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New England Water Works Association
1957-1958

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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 1000 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

Initiation Fees		*Annual Dues*	
Members	$ 5.00	Members	$ 5.00
Juniors	1.00	Juniors	3.00
Associate	10.00	Associate	25.00
Corporate Members	10.00	Corporate Members	15.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.

. . . with the greatest of ease

CUSTOMER

It fits in our budget with greatest of ease,
With savings at which no smart buyer can sneeze,
Low cost plus long life and best service he sees
Mean premium pipe at low pay.

CONSULTANT

It matches our plans with the greatest of ease,
Complete with bends, shorts, Y's, adapters and T's,
Designed for what pressure or backload we please,
The pipe we are proud to OK.

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It goes in the ground with the greatest of ease,
Is rapidly jointed come storm, heat or freeze,
No caulk, bolt or weld—installation's a breeze,
And backfilled the very same day.

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It carries full pressure with greatest of ease,
Corrosion and tubercles never displease,
High maintenance costs never put on the squeeze
With uncalled for bills to defray.

LOCK JOINT CONCRETE PRESSURE PIPE for this QUARTET!

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It fills all our needs with the greatest of ease,
It's thrifty yet safe everybody agrees,
No wonder we all say, "No substitutes, please!"
When Lock Joint's the best pipe to lay.

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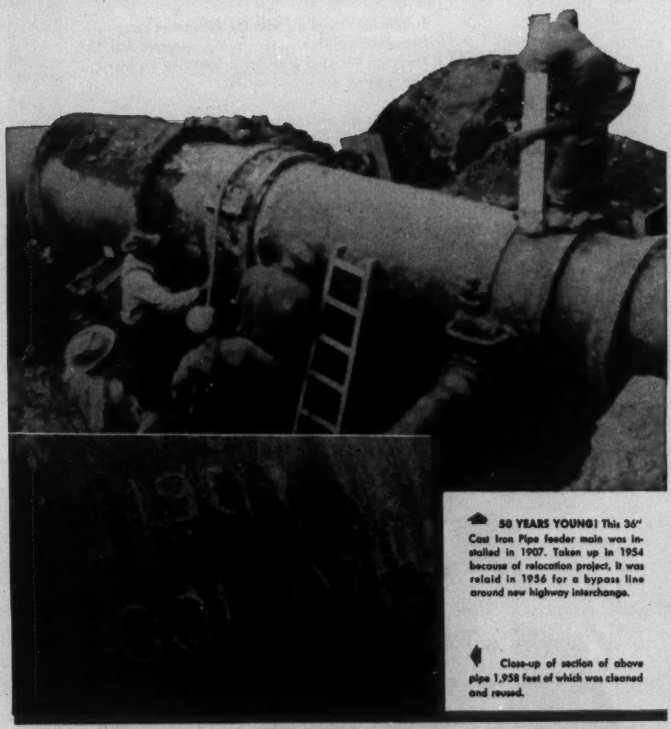
ANY PIPE CAN PROMISE...

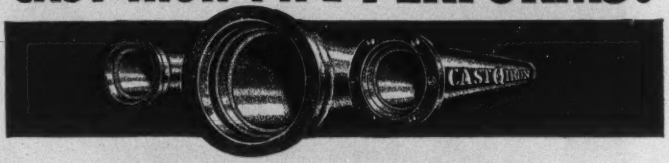


50 YEARS YOUNG! This 36" Cast Iron Pipe feeder main was installed in 1907. Taken up in 1954 because of relocation project, it was relaid in 1956 for a bypass line around new highway interchange.

Close-up of section of above pipe 1,958 feet of which was cleaned and reused.

MODERNIZED **cast iron**

CAST IRON PIPE PERFORMS!



What other pipe offers you LONG LIFE + STRENGTH + HIGH FLOW CAPACITY?

Don't doubt when you buy pipe—specify cast iron and be sure of...

1. **LONG LIFE...**
   42 North American cities are still using cast iron water mains laid 100 years and more ago. Hundreds more have passed the 50 year mark.
2. **BEAM STRENGTH...**
   Cast Iron Pipe is inherently tough... stands up under heavy traffic load, soil displacement and disturbance.
3. **HIGH FLOW CAPACITY...**
   Cement lined cast iron pipe and fittings will not tuberculate... delivers a full flow for the life of the pipe.
4. **EXTERNAL LOAD RESISTANCE...**
   6" Class 150 Pipe withstands a crushing load of 17,900 pounds per foot... nearly 9 tons.
5. **CORROSION RESISTANCE...**
   Cast Iron Pipe effectively resists corrosion... vital factor in its long life and dependability.
6. **TIGHT JOINTS...**
   A full range of leak-proof, low cost, easy-to-assemble joints for pipe and fittings are available for all conditions.

You've read and heard thousands of words—all selling pipe.

But make no final choice before you ask this simple question: What pipe offers you not one, not two but *all* the factors that spell long, trouble-free life and dependability.

The answer is... cast iron pipe. Performance made it... and performance keeps it... America's No. 1 Water Carrier.

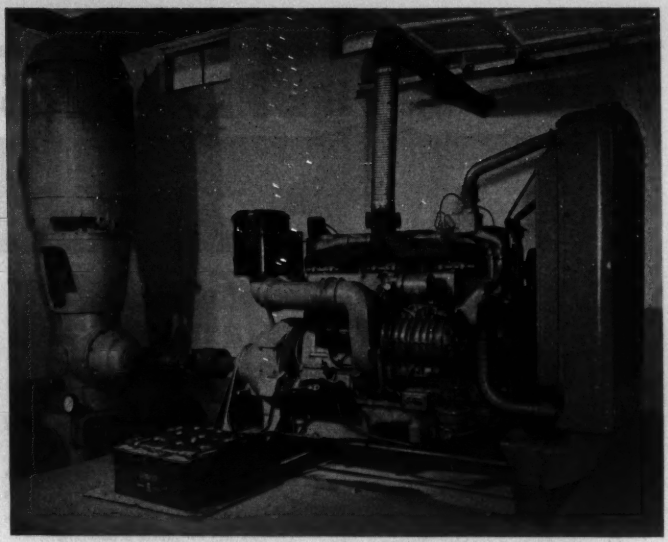
Its service record *proves* it!

THE MAN WHO CHOOSES CAST IRON PIPE TODAY WON'T PAY FOR IT AGAIN TOMORROW!

CAST IRON

Cast Iron Pipe Research Association
Thos. F. Wolfe, Managing Director
Suite 3440, Prudential Plaza, Chicago 1, Ill.

pipe FOR MODERN WATER WORKS



Diesel Engine Driven Pump Unit at Westfield Pumping Station, Westfield, Massachusetts

Designed and engineered by Mr. Don Weinle, City Engineer, the new Westfield Pumping Station includes a Cummins Model HRS engine, driving a Worthington vertical turbine pump through a U. S. Motor right angle drive as stand-by for electric power. Capacity is in excess of 2,000,000 gallons per day.

The new equipment was installed in November, 1957.

CUMMINS DIESEL OF NEW ENGLAND, INC.

201 Cambridge Street
ALLSTON 34, MASSACHUSETTS

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720 Union Street
WEST SPRINGFIELD, MASSACHUSETTS

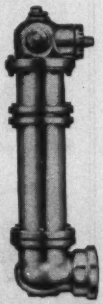
Our representative can explain to you how simplicity of design minimizes maintenance—and to see the R. D. Wood Hydrant you needn't leave your office chair.

"Don't Get Up! Sit Right Where You Are and Let Me Show You the R. D. Wood Hydrant"

"With this scale model I can show you why the R. D. Wood Hydrant has earned its reputation for reliability, strength and permanence. It is simple in construction, too—a fact that makes it low in cost and easy to repair in case of accident.

"The full area main valve is cone shaped to prevent water hammer. It opens *against* water pressure, so that if it is broken in a traffic accident, water pressure will hold it closed. This prevents loss of water, lowering of water pressure, and flooding."

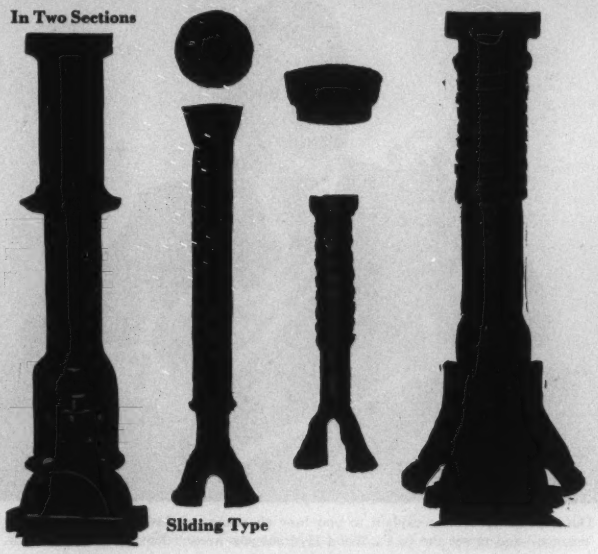
Would you like to see it? Our representative will bring in a scale model and show you its advantages right in your office. Drop us a line today and he will telephone you for an appointment at your convenience.



R. D. WOOD COMPANY

Public Ledger Building, Independence Square, Philadelphia 5, Pa.

Manufacturers of Mathews Hydrants and "Sand-Spun" Pipe (centrifugally cast in sand molds)



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1. *Standardization*
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3. *Quick Delivery*

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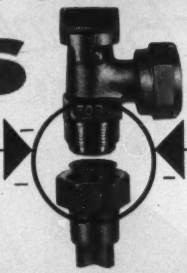
Genuine Buffalo Cast Iron
Service. Valve. Roadway and Meter Boxes
Manhole Frames and Covers

CULPEPER, VIRGINIA

...why didn't FORD think of THIS before?



Now that we have started making the new Ringstyle Valve for copper connections, we've wondered, too, why we didn't think of this simple idea sooner. Now that we have, a patent is pending.

Of course we were proud of the old arrangement. When we introduced the Ringstyle Valve in 1938 it was a brand new idea and the meter coupling nut attached to the valve was an important development in meter setting. But the old design, with its loose ring for connecting the valve to copper, had its disadvantages.

But look what we've done with this new one. We've built the beveled end right onto the valve itself and reversed the thread arrangement. Thus, the standard copper tube nut fits right on the new Ford Ringstyle Valve for an easy-to-make, leak-proof joint. The capacity is not reduced — The appearance and utility are improved.

Former Design

The men who install this new Ford Ringstyle Valve will certainly approve this change because there's no loose ring to drop into the mud or dirt in the ditch. Connecting the valve to the copper service line is simpler, easier and quicker.

Write for information and sample.

FOR BETTER WATER SERVICES

FORD

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Connect Branch Mains...

QUICKLY SAFELY SIMPLY *under pressure!*

MUELLER® Tapping Sleeves and Valves are your most practical—and economical—means of connecting lateral or branch mains.

Connections are quickly made under pressure with the new Mueller CL-12 Drilling Machine—*there is no shutdown, no loss of water, no interruption of flow in the main!*

Mueller Tapping Sleeves are designed to actually strengthen the main at the branch main connection where high stresses can be created by any movement of the branch main.

Calked or mechanical joint type sleeves and valves are available to fit your individual needs. Full range of main and branch main sizes.

Consult your Mueller Representative or write direct for full details and be sure to get your copy of the free folder on the new CL-12 Machine.

MUELLER CO.

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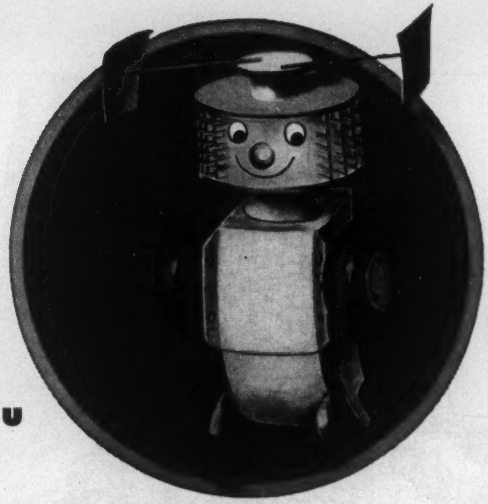
Factories at: Decatur, Chattanooga, Los Angeles; In Canada: Mueller, Limited, Sarnia, Ontario



have you met

Dr. Centriline . . .

If not, you should! He can do things for you . . . like making your job easier and saving you money. He's a versatile and somewhat ingenious many-armed creature who specializes in cement-mortar lining the inside of pipes. And he's done this to over 4 million feet of pipe, too—eliminating corrosion and tuberculation . . . increasing flow capacity . . . reducing leakage . . . slashing pumping costs . . . and adding years and years of pipe life. If you'd like to learn more about Dr. Centriline and how he can work for you, just write or call for one of our descriptive brochures.

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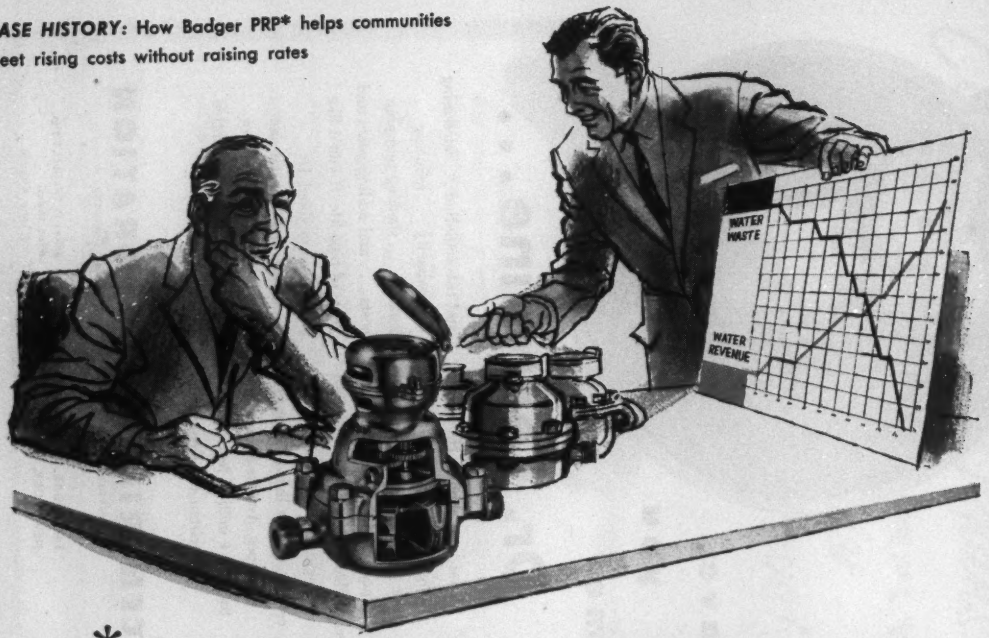
• CEMENT-MORTAR LINING OF PIPES IN PLACE •

CASE HISTORY: How Badger PRP* helps communities meet rising costs without raising rates



*Planned Rehabilitation Program helps city

account for 94% of water used

through annual "roundup" of defective meters

A near impossible record — but this Midwestern city did it! The community (name on request) began metering when it started its water system back in 1882. One of the nation's first cities to be fully metered, it initiated a planned meter rehabilitation program at the outset. Result: low water waste, high water revenue — as much as 94% of *all* the water used is "accounted for."

Badger's Planned Rehabilitation Program has helped communities all over the country keep their water systems on this same profitable basis. They're installing new, accurate Badger meters where it is economically feasible... new essential parts where only minor repairs are needed.

Is your water department paying its way?

If not, it's time your community held its own water meter roundup — to open the way to new revenue . . . end water waste from worn-out meters and parts . . . even help meet rising water department costs. Send for free booklet, "Take 5," outlining the 5 steps to increased revenue through Badger's Planned Rehabilitation Program.

And be sure to ask your Badger representative about our liberal water meter trade-in policy.

Badger Water Meters

BADGER METER MFG. CO. • 4545 W. Brown Deer Rd.
Milwaukee 18, Wisconsin

Research makes the big difference in meters Badger builds...

New features for water meters are constantly being developed and tested in Badger's engineering and research departments. Here a chemist inspects plastic specimens tested for dimensional stability. To his right, a test of registers operating under water determines corrosion resistance . . . and an electrolytic analyzer is making a quantitative analysis. From these tests and others will come still greater efficiency and proven durability for future water meters—first from Badger.

BADGER METER MFG. CO.
Dept. C-1, 4545 W. Brown Deer Rd.
Milwaukee 18, Wisconsin

Gentlemen:
Please send me your free booklet, "Take 5."

Name_____

Title_____

Address_____

City_____ State_____

ANOTHER FAIRBANKS-MORSE LEADER

City of Taunton — Harris Street Pump Station

Illustrating 2 Fairbanks-Morse motor-driven, 4 MGD Fairbanks-Morse centrifugal Figure 5814 Pumps, and 1 - 6 MGD Fairbanks-Morse 300 HP diesel-driven Fairbanks-Morse Figure 5814 Pump.

Designed and engineered by Fay, Spofford & Thorndike, Inc., Consulting Engineers.

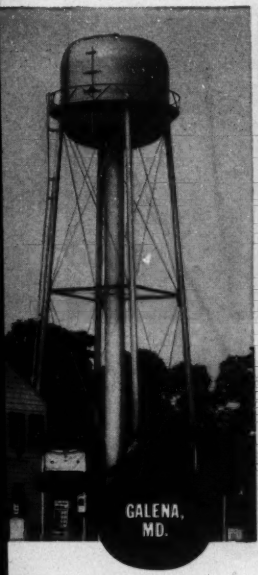
Write or telephone to:

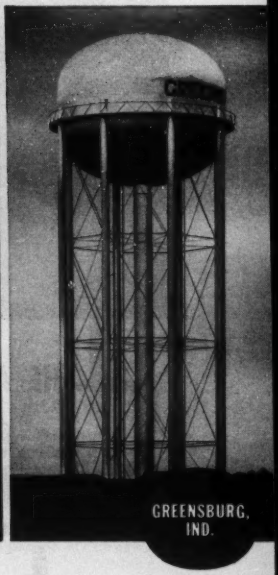
FAIRBANKS, MORSE & CO.

178 Atlantic Avenue **Boston 10, Massachusetts**

Telephone: LAfayette 3-3600

50,000 Gallons **150,000 Gallons** **500,000 Gallons**





...the capacities to serve your needs

...top economy and appearance, too!

PITTSBURGH
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Double Ellipsoidal
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STEEL TANKS

Pittsburgh-Des Moines' Double Ellipsoidal Elevated Steel Tanks offer an advantageous combination of economical design and pleasing good looks, meeting today's exacting community standards. With very low head ranges in sizes to 300,000 gallons, and good head ranges up to 750,000 gallons, the Double Ellipsoidal tank design covers at low cost the greater part of all municipal water storage requirements. Write for our illustrated brochure detailing the complete range of PDM elevated tank types and capacities.

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produces, FIRE HYDRANTS A. W. W. A. Specification and High Pressure — Compression Type — Dry and Wet Barrel Types. GATE VALVES sizes 2" thru 66", Manual, Hydraulic Cylinder, Electric Motor Operated for Low, Medium and High Pressure Service. INSERTING VALVES sizes 4" thru 48" for inserting under pressure. TAPPING SLEEVE AND VALVES sizes 4" x 2" thru 60" x 48" for branch connections under pressure.

42

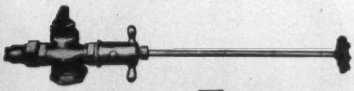
THE A.P. SMITH MFG. CO.

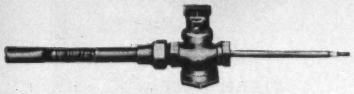
EAST ORANGE, NEW JERSEY

Now - - with an AQUA - STOP
you can change leaking or defective curb stops under pressure

Think of it!

With the simple tool shown you can replace old or leaking curb stops under full pressure! No breaking into expensive roadways. Only one hole to dig — and no water or mud!





In six easy steps, as simple as this —

1. Insert the AQUA-STOP in the outlet side of the curb stop.

2. Push the plunger through the open curb stop. Turn the hand wheel on the AQUA-STOP, and all flow through the line is stopped.

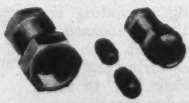
3. Remove the body of the AQUA-STOP.

4. Remove the curb stop. The AQUA-STOP will hold the full line pressure as long as you want it to.

5. Replace the curb stop with a good one, replace the AQUA-STOP body, again turn the hand wheel, and withdraw the plunger.

6. Turn off the new curb stop, remove the AQUA-STOP and the job is done. Only a cup of water lost! And SO SIMPLE TO OPERATE.

AQUA-STOP FOR ¾" CURB STOPS, complete with Iron Pipe Thread Outlet and Flare-Type Copper Tube Outlet. Complete, $27.95



PIPE LINE EQUIPMENT

JOSEPH G. POLLARD CO., INC.

PIPE LINE EQUIPMENT

PIPE LINE EQUIPMENT

Place your next order with POLLARD

If it's from POLLARD — It's the Best in Pipe Line Equipment

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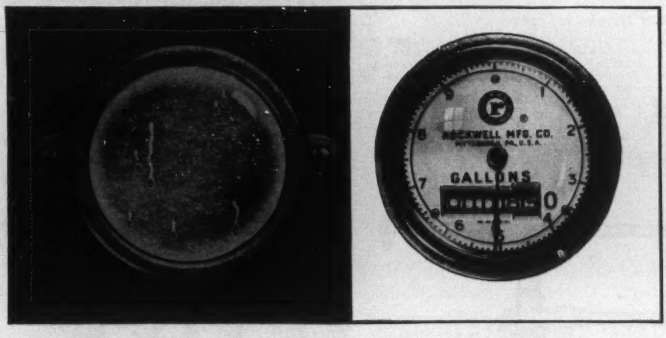
What good is a meter

if you can't read it?



DIRTY FACE

Condensation and dirt cloud the dial on this conventional register.

CLEAN FACE

Rockwell hermetically sealed register always presents a "clean face" to the meter reader.

YOU CAN ALWAYS READ A ROCKWELL SEALED REGISTER WATER METER

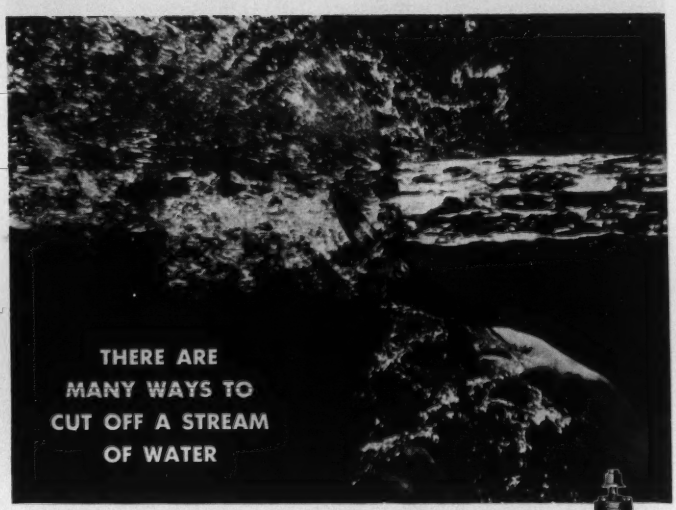
In recent years water utilities have spent thousands for oil enclosures, wipers and similar gadgets to lick the problem of fogged registers. Now, for not a penny extra, Rockwell offers a revolutionary new meter having a hermetically sealed register which completely eliminates condensation under the glass.

In the Rockwell Sealed Register meter all gearing, including the intermediate train, is encased in a sealed compartment high and dry above the measuring chamber. There's no stuffing box to leak or bind. A powerful magnetic coupling transmits motion smoothly and with the least possible friction. All this means less wear, less chance for corrosive attack, and, of course, easier maintenance at lower cost. Get full facts now, *write to Rockwell Manufacturing Company, Pittsburgh 8, Pa.*

SEALED REGISTER METERS

another fine product by

ROCKWELL



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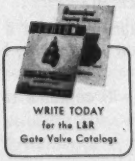
Because Ludlow gate valves and Rensselaer gate valves assure *ease of operation, watertight closure and years of trouble-free performance.*

Combining simplicity and soundness of design with high quality workmanship, Ludlow and Rensselaer gate valves meet all the requirements of exacting engineers and water superintendents — and exceed A.W.W.A. specifications.

Ludlow and Rensselaer double disc gate valves offer the most complete selection of outstanding design features available today, plus custom design engineering for special applications. Sizes range from 2" to 72".



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BRANCHLINE CONNECTIONS TO MAIN LINES UNDER PRESSURE are made easier and more dependable by Ludlow and Rensselaer tapping sleeves and valves.

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THE LUDLOW VALVE MANUFACTURING CO., INC., TROY, N. Y.—SINCE 1861

Do you have AUTOMATIC MODERNIZATION in your water system?

If you have Trident water meters, your department is probably the only service in your community equipped with *Automatic Modernization* . . . a process which costs far less than "scrap and replace" programs.

Every time you replace work-worn parts in a Trident disc meter, you automatically use modern parts identical to those in the *latest* model . . . parts embodying every thoroughly tested advancement known to the science of metering.

No need to keep complicated stocks of parts for many models . . . just keep a small stock of modern parts. It's easier to train service men, too. Your men need learn only one simple, fool-proof model, and they can service all.

Designing modern Trident parts so they'll fit "old" meters has been a rigid Neptune policy for 60 years. *Every design improvement now on our drawing boards will continue this policy.*

It's your best assurance that the meters you buy today will continue to earn more and cost less for many decades to come.

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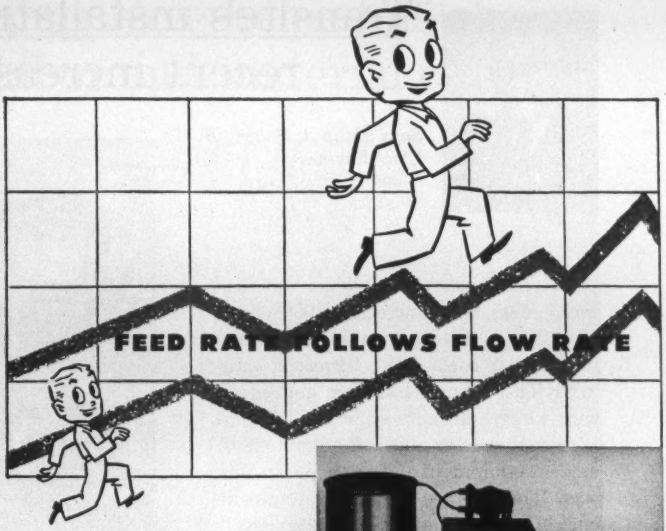

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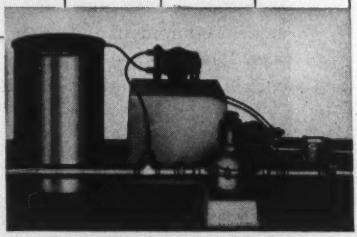

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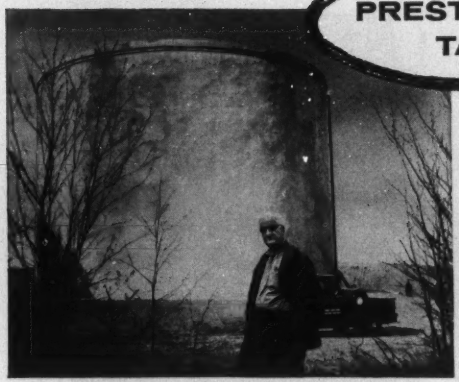

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MANAGEMENT AND THE WATER INDUSTRY*

BY F. H. BULLOCK, B.Sc., M.I.C.E.

INTRODUCTION

The subject of this paper, which was written at the invitation of the President, Mr. Wm. C. Knill, is one of great importance, but the author would like to make it clear at the outset that he does not regard himself as qualified to do more than to provide a brief and inadequate introduction to the subject. Nevertheless, he trusts that it will be of interest to all those members —and they are in the majority—who have to exercise managerial responsibility in greater or lesser degree.

MANAGEMENT IN THE WATER INDUSTRY

It is the experience of the majority of the members of the Institution, not only to find themselves carrying out duties of an administrative or managerial nature, but also to discover that these tend to occupy an increasing proportion of their time, while work of a purely engineering character has very largely to be delegated to others.

In Appendix "A" of the Ministry of Education pamphlet "Education for Management" (H.M.S.O. 1947) is given an analysis of a random sample of the corporate membership of two engineering institutions and one accountancy institution. Seventy-five per cent of the members of the two engineering institutions had some degree of responsibility for management, while in the third institution the proportion was 66 per cent. Of members with high administrative responsibility the three institutions had the following percentages—18, 9, and 11½ per cent, respectively. It might be said, then, that roughly 70 per cent of those whose

*At the Palace Hotel, Southend-on-Sea, Wednesday, 13th May, 1953.

Editor's Note: This paper is reprinted from the *Journal of the Institution of Water Engineers* (London), Vol. VII, No. 5, Aug., 1953 (p. 392). The author was awarded the reciprocal diploma from the New England Water Works Association in May, 1958.

initial qualifications were either technical or professional engage at a later date in managerial functions.

Henri Fayol, an early investigator in the subject, said that employers required these abilities in varying degrees: managerial, technical, commercial, financial, security and accounting; he added that the manager's functions might be 40 per cent managerial, 15 per cent technical, 15 per cent commercial, and 10 per cent each financial, security, and accounting.

The Institution has not, until recently, devoted time to a consideration of members' activities in management. More and more, however, it is being recognized that successful practice as an engineer depends very largely on competence as a manager, that is, as a controller of men. As engineers, we receive, in most cases sound and perhaps first-class education and training, followed by ample experience. As managers, however, few of us are fortunate enough to receive any education or training, and we pick up our experience as best we can as we go along. This is a very unsatisfactory position, and the need of managerial training is now generally admitted throughout British, Continental, and American industry.

While the water industry and other public utilities differ considerably from manufacturing industry or commerce, there are factors common to all of them. They exist, in fact, wherever some men have the duty of efficiently controlling the activities of others, whether it be in industry, government departments, or the services. Some of the most successful leaders of recent years in all fields have been those who have studied and applied the principles of scientific management.

Management Study Group

It is due to Mr. Delwyn G. Davies that the Institution, through a Study Group set up in 1951, has given some time and thought to the problems of management in the water service. In December 1950, Mr. Davies suggested that research should be instituted into waterworks management, and, as a result of this approach, a study group was formed consisting of the following members: Messrs. L. H. Brown, F. H. Bullock, D. G. Davies, K. L. Forster, Wm. C. Knill, H. R. Lupton, P. Porteous, and N. A. F. Rowntree.

The Group has submitted a preliminary report to the Council and has also prepared a number of notes on various aspects of the subject. Several of these have been used as the basis of paragraphs here, including those entitled "History of the Art of Management" and "Management Theory".

Objects of the Institution

It has been suggested that the prime purpose of the Institution is "to promote the advancement of water engineering", and that members of the Institution should not, as such, concern themselves with questions of administration and management. That this narrow interpretation of the aims of the Institution was never intended by its founders is made clear from an examination of the Institution's Memorandum of Association. The words quoted above occur in clause (3) of the Institution's Objects, and continue ". . . and all matters connected with, or relating to, water undertakings". Other clauses are more specific. Clause (4), for example, refers not only to water engineering but to ". . . the finance, management and administration of water undertakings."

Manual of British Water Supply Practice

Chapter 25 of the *Manual** provides a valuable basis for the study of the organization and management of water undertakings, but, being a manual of present practice, does not deal with the subject of scientific management or the art of management. During the last 50 years or so, it has been increasingly recognized that there are rules and precepts which have general application where some have the responsibility of guiding and controlling the actions of the many. The attempt is made in this paper to relate the discrete science of management, as now regularly studied in industry and commerce, with the particular conditions and needs of the water industry.

Special Factors

The following are some of the factors which differentiate water undertakings, and to a varying extent other public utilities, from industrial enterprises:—

*An alphabetical list of references is given in the Bibliography pp. 249-250.

(a) Water undertakings are, in effect, statutory monopolies, their activities being very closely controlled in the public interest. The absence of competition avoids wasteful overlapping of effort, but also, it must be admitted, tends sometimes to induce satisfaction with low standards of performance and old-fashioned methods.

(b) Their prime purpose is to provide a public service and not to make profits. Rates of interest and dividend are limited.

(c) They cannot be allowed to fail in their duty, or to close down for any reason. Thus, their continued existence in some form is guaranteed by the Government.

(d) The shareholders' and bondholders' investments are safe, and, generally speaking, undertakings are permitted to make changes which enable them to pay interest on their borrowings, and a reasonable dividend on stocks and shares.

(e) The paramount need for reliability of supply engenders a conservative attitude towards new methods and materials. Added to this, the limitation of water charges results in a lack of funds to finance experimental work, and to introduce and develop new ideas and techniques.

(f) Water undertakings are obliged to lay mains and to provide supplies, under penalty. They cannot choose their consumers, nor can they plan their development as they might wish. They have to follow willy-nilly whatever housing and industrial development occurs.

(g) They have to provide a continuous day and night service.

(h) They are more subject to natural circumstances and caprice than most enterprises, e.g. their sources of supply are scattered, and are the result of geological accident. In the case of undertakings which collect or impound their supplies, they are also affected by the erratic incidence of rainfall.

(i) Their situation, topography, types of supply, soils encountered, and quantity and quality of water sources available all vary greatly, so techniques and constructional work cannot be closely standardized, though much has been done during recent years towards this end.

(j) There are so many variables, that it is difficult to make comparisons between undertakings. There are no standard criteria of efficiency; each undertaking must have its own.

(k) By their nature, they cannot be grouped around centres of suitable labour, so there is little opportunity of acquiring workers from local pools, as many industries can do, e.g. shipbuilding or needle-making. There is thus a need for training within each separate undertaking.

(l) Their employees are usually comparatively few, and are, for most of the time at any rate, dispersed over large areas. This makes detailed supervision difficult, and individual workers have to be trusted to a much greater extent than in industry generally to work without being overlooked.

(m) Supervision has to be largely geographical, and foremen and superintendents usually control very mixed, as well as scattered, labour forces. Functional supervision (control of each type of worker by a specialist) is impracticable, or possible only in a comparatively small field.

(n) Within each undertaking, there is great diversity of function, and the numbers of each type of operative or worker are small. This complicates the problems both of control and of training.

(o) Planned work and output, now general in factory production, may be possible in the supply works, but much of the work of a water undertaking consists of maintaining the network of mains and services. This involves repair work carried out over a wide area, and little planning is possible. Flexibility of operation has to be aimed at. Even such work as service laying is largely adventitious. Planned work-flow, and similar terms used by the efficiency expert in manufacturing industry, are out of place when considering the operation of water undertakings.

(p) Labour conditions are not very attractive, by comparison with some other sections of industry. The security of work in the water industry used to compensate for the relatively low earnings and absence of opportunities for advancement. This factor is now largely inoperative, as the policy of full employment has eliminated much of the irregularity of employment, which was a feature of many sections of industry prior to 1939.

(q) High earnings in industry are usually derived from payment by results, but as piecework and bonus schemes are seldom applicable in water undertakings (except in such work as the laying of mains in rural areas), opportunities for high earnings

rarely exist. Due to this reason and to the fact that chances of promotion are few, many workers prefer other kinds of industry; yet there are usually a sufficient number of workers available who appreciate the comparatively quiet conditions within the water industry. Such men often make reliable workers, and they are less likely to leave to seek other and more profitable fields of employment than are the more ambitious.

Publicly Owned and Company Authorities

Some of the principal differences between company and municipal undertakings are set out in this table:—

Companies	*Public Authorities*
(1) Share capital is raised by sale of shares or stock (competitive tender) and loan capital by sale of debentures (sometimes by tender).	Money for capital works is raised either by borrowing from the Local Loans Board or by making loan stock issues in the open market.
(2) Capital raised is not repayable. When redeemable stock is issued it can only be redeemed by making a further capital issue. Thus the total amount of stock issued increases steadily.	Capital must be repaid during or at expiration of the term of the loan. The total of outstanding loans may increase or decrease.
(3) Water charges must be sufficient to cover all expenses, including loan interest, and should permit the payment of dividends within maxima laid down by statute.	Deficiencies in income may be made up by a rate in aid, in respect of municipal undertakings, or by precept in respect of water boards.
(4) Company accounts are governed by the Companies' Acts, either directly or by the incorporation of the latter in private Acts.	Most public authorities' accounts are subject to examination by the district auditor. (In boroughs certain alternatives exist.)
(5) Companies are controlled by boards of directors, usually numbering 5 to 10 members, appointed by the shareholders.	Public authorities are controlled by committees, the members of which are in most cases publicly elected council members. Such committees may sometimes be quite large, numbering up to 60 or more.
(6) Directors are elected for three years, and are usually re-elected.	Members of committees or water boards are elected for three years, but sometimes for shorter periods.

	They are often eligible for re-election, but the tendency is towards greater changes in personnel than occur in boards of directors.
(7) Directors receive fees for their services.	Members of committees are unpaid.
(8) In general, companies are rather more free to operate, and to modify their organization within the limits laid down by statute.	Public authorities' undertakings possess rather less freedom to act and to change their organization, partly because of the need to consider the position of other departments of the authorities involved.

The Chief Officer

In all, or almost all, water undertakings in this country, policy making and overriding control are in the hands of boards or committees comprising part-time members. Occasionally, in water companies, a managing director is appointed, who not only shares with his colleagues on the board of directors the responsibility of policy forming, but has also the duty of managing the undertaking, and of putting the board's policy into effect. The system of full-time directorates, which is found widely in manufacturing industry and commerce, does not exist in the waterworks world.

Frequently, and, according to some authorities, more satisfactorily, the policy-making body governs the undertaking through a single chief officer; but sometimes there are two officials, both ranking as chief officers, i.e. they share executive duties in greater or lesser degree. It is not possible here to set out all the variants which exist. The main functions to be carried out by the chief officer or officers are:—

(1) General management, including assistance in policy-making.
(2) Financial management.
(3) Personnel management.
(4) Office management, including purchasing and sales.
(5) Engineering, including production, distribution, maintenance, development, and construction of new works.

The order in which these functions are set out is not intended to indicate their relative importance.

The engineering section must, of course, be controlled by a

qualified engineer. The financial and personnel management of the undertaking, in all but a few cases, should be under the control of the engineer, since, by the nature of water undertakings, the latter is responsible for most of the expenditure, and has to organize and supervise the majority of the labour employed. Engineering is the basis of the operation of all water undertakings, as it is, in fact, of a large proportion of manufacturing industry. For this reason the chief official generally is, and should be, the engineer. If the control of the undertaking is in the hands of the engineer, he will be assisted by the clerk or secretary, who, to a greater or lesser extent, will possess independent responsibility, particularly on the financial, accountancy, and legal sides, and will report direct to the board or committee.

If the above dictum is accepted by engineers, it follows that they must take every step open to them to secure an adequate training and education in management, and to obtain such experience as will make them competent.

Evolution of Waterworks Management

(1) Though water undertakings have come into being in a number of ways, probably the majority started as private speculative enterprises, or as companies. Large landowners took the lead in many instances, their aim being to develop their land or to enhance its values. Some undertakings have grown from estate schemes designed originally to supply landed proprietors and their tenants.

(2) Until about the middle of the 19th century, most undertakings were company undertakings, but from then on the gradual tendency has been for local authorities, singly or in groups (water boards), to take over company projects. Notwithstanding this, large numbers of companies are still in existence, some of them being as large as any but the largest municipal water authorities.

(3) The original entrepreneurs were in most cases non-technical men, and they often placed the control of their undertakings in the hands of solicitors or accountants, who acted as clerks or secretaries. The engineering works were often constructed by consultants, who would occasionally assume some responsibility for their maintenance and operation, but not for the day-to-day administration. A few consultants acquired finan-

cial interests as shareholders and directors of water companies, and this is still true to-day.

(4) It was found necessary in most instances to appoint full-time engineers to conduct the day-to-day engineering work of plant operation and mains extensions, as well as the construction of new works. Municipal authorities, however, have often expected their engineers or surveyors to undertake these additional responsibilities.

(5) Recognizing that the principal functions of water undertakings are of an engineering nature, the majority of water authorities have placed the responsibility for management in the hands of their engineer, who most often is described as engineer and manager. (Note that the engineering function appears to have been regarded as of first importance.)

(6) In some instances, however, management and administration are shared between the engineer and the secretary, and in others the secretary is the chief executive official. Occasionally there is a general manager or a managing director in control, with an engineer and a secretary in secondary positions. Elsewhere, the duties of secretary are assumed by the engineer-manager.

(7) Rural undertakings of small size are often looked after by individuals with no special aptitudes or training, and this is true both of companies, and local authority undertakings, where perhaps an overworked sanitary inspector adds the responsibility for water supply to many other duties.

(8) In manufacturing industry, the size of many concerns, and the large numbers of workpeople employed, have brought about subdivisions in management to specialize in production, personnel control, and so on. This development has not reached the water industry, nor is it likely to so long as even the largest water undertaking employs only between 3,000 and 4,000 people.

Training of Water Engineers

In December 1944, the Council of the Institution adopted a report on the recruitment and training of water engineers, which well repays study. Paragraph 12, "Non-Technical Education," states:—

> "As the majority of water undertakers require their engineer to occupy also the position of manager of the undertaking, it is necessary

for the engineer-manager to have a wide grasp of administrative matters, to which, in the normal course of practice, a great deal of time is devoted.

"It is recognized that engineers acquire a rudimentary knowledge of administrative subjects in the course of their experience in junior positions, but it is felt that this means of becoming acquainted with matters of such great importance is much too casual and unsatisfactory. The possibility of holding examinations in such subjects has been considered by the committee and rejected on various accounts, including recognition of the fact that examination success is not necessarily indicative of proficiency in practice."

One might quarrel with the title of this section of the report, for it is now accepted that management has its own technique, and therefore education for management is more properly described as technical education. The trained manager, whether he be an engineer or not, is a technician, skilled in that most difficult of arts, the handling and control of human beings. As to examinations, there are now a number organized by various professional management bodies, and it can be said that a real beginning has been made with what has been called (with more accuracy than felicity) the professionalization of management. Failure by the engineer to acquire competence as a manager by education, training, and experience, may result in his subservience to others who have been so trained.

Amalgamation of Water Undertakings

In present circumstances, when there is a tendency towards the amalgamation of water undertakings into larger units, problems of management and administration may prove even more formidable than those of engineering and finance. It is perhaps not altogether accidental that three members of the Study Group are, or have been, engineers and managers of undertakings which have resulted from the merging of a number of others. One of them, Mr. N. A. F. Rowntree, wrote a most interesting paper on the subject of amalgamations in 1950, while another, Mr. L. H. Brown, has presented a paper at the Summer Meeting this year (July 1953 *Journal*, p. 347). The third, Mr. Delwyn Davies, wrote, in 1950, for the Northern Section, a paper entitled "Waterworks Organization—The Problem of Size".

The special problems relative to amalgamations and the

efficient operation of the resulting undertakings, particularly when these are large, have by no means been fully solved, and it is interesting to study in this connexion a book edited by G. E. Milward, entitled "Large-Scale Organization", where this admission is made. There is urgent need for study of the human and other problems common to all amalgamations, in order that a body of principles may be evolved, as an extension to the general theory of management.

History of the Art of Management

When one considers that large industrial enterprises, employing many workpeople, have existed for a couple of centuries, it is remarkable that so little was done until comparatively recently to determine the principles upon which the successful control of business undertakings depends. This body of principles is known as the art of management. Although many aspects of the subject, particularly those relating to large-scale undertakings, are still little understood, the fact that there are well-defined principles of management which lend themselves to scientific analysis and evaluation justifies the increasing use of the term science of management.

There are perhaps four main reasons why the subject received so little attention in the past:—

(a) The difficulty of discovering and analysing the many factors influencing human conduct.
(b) The ample supply of cheap labour in England at the time of the Industrial Revolution.
(c) The workers' lack of education and of political power, which made difficult any effective protest by them against wasteful, and sometimes inhuman, conditions of employment.
(d) The owners' widely held conviction, which even to-day has not disappeared, that they were well able to manage their own concerns without specialist assistance.

It is perhaps significant that the first real attempt to explore management problems was made in the United States, where the scarcity of labour drew attention to the need for efficiency in its utilization.

In the early days, industrial enterprises were small, and could be satisfactorily controlled by one man, who was often the sole owner. As the units of industry became larger, there

appeared a new class of individual, the manager, to form a vital link, a sort of third estate, between ownership on the one hand and the workpeople on the other. Over a century ago it was realized that management was the principal creative element in economic organization, and since that day many attempts have been made to establish and systematize general principles which would be applicable to every type of enterprise. As may be expected from an activity so new in human society, much that has been said and written on the subject is of little value, and confusion of thought has been created by the employment of unscientific jargon.

Prominent among those who developed the new science of management can be mentioned the following, all of whom, except Babbage and Fayol, are American:—

Professor Charles Babbage of Cambridge, a mathematician, who wrote his "Economy of Machinery and Manufactures" in 1832.

F. W. Taylor, an engineer and inventor, whose "Principles of Scientific Management" appeared in 1911.

F. B. Gilbreth, a civil engineering contractor, who introduced Motion Study and Fatigue Study, and wrote books with these titles in 1911 and 1919.

H. L. Gantt, also an engineer, who published "Organizing for Work" in 1919, and was responsible for the development of visual methods of control, including charts of various types.

Henri Fayol, French steel manufacturer, whose "Administration Industrielle et Générale" was written about 50 years ago.

Henry Ford, motor car manufacturer and pioneer in mass-production, whose work between 1900 and 1925 had a profound effect on industry generally.

Mary Parker Follett, political scientist and organization specialist, who in the first quarter of this century showed that the problems of government and of industrial management were largely the same.

Dr. Elton Mayo, leader of a team of research scientists from Harvard University, who carried out exhaustive experiments with small groups of workers. This was the first time that the dynamic aspects of management were subjected to prolonged experiment. He is still engaged on this work, and in 1933 and 1945 wrote on the Human and Social Problems of an Industrial Civilization.

It is no accident that engineers have taken the lead in the establishment of the art of management, since engineers, during the past 100 years, have been responsible for almost all the main developments of industry.

In this country we can justly be proud of the early work done by Babbage on management method, costing and time study, yet little or no notice was taken of his writings. Taylor was a real innovator, and his work was revolutionary. He gave much time, as stated by Col. L. Urwick (1949a), to many aspects of the relations between worker and management, including ". . . work analysis, study of elements, time and motion study, definition of each man's task, selection and training of personnel, standardized performance under standardized conditions, exact and detailed instructions, confidence built on demonstration that the task can be accomplished, control to see that conditions and performance are secured, gradual development of change and high pay for success. On the management side, we find specialization and functionalization, definition of responsibility and squaring it with authority, separation of planning from execution, decision (not 'trying things'), pre-planning of work, economy of effort by the 'exception principle,' active interest in promotion and constant co-operation with the men. It is not too much to say that there is hardly a principle or device underlying modern production control, and accepted to-day as normal practice, which cannot be traced to his initiative".

We may expect, and indeed should encourage, an intensification of management studies, now that the need for efficiency in industry is so widely recognized and has so intimate a bearing on every aspect of our national safety and well-being.

Urwick suggests that much of the development assigned to technical originality and inventiveness should have been credited to managerial capacity. For instance, he states, James Wyatt, of Birmingham, invented a spinning machine 30 years before Arkwright, but, having no capacity for organization or for controlling men, his labours bore little fruit. The converse was presented by Dr. Ure, writing in 1835 on Philosophy of Manufactures: "To devise and administer a successful code of factory discipline . . . was the Herculean enterprise, the noble achievement of Arkwright".

In 1832, the Lucasian Professor of Mathematics at Cambridge, Charles Babbage, wrote that, having visited a considerable number of workshops and factories here and abroad, he was led to apply to them the principles of generalization which he

had already begun to formulate. His book, "Economy of Machinery and Manufactures," contains hints of several modern methods of management, including analytical costing and time study.

These, and others mentioned in a preceding paragraph, were principally concerned with factory management, though Henri Fayol applied to the task of administration the techniques of analysis and measurement which had been used by Taylor, Gilbreth, and Gantt in America in examining the work and movements of the individual operator or workman. He claimed that his theory of administration was applicable to any form of organized undertaking, and was employed by the French Government in a reorganization of the Post Office.

Other examples of the application of scientific management to great enterprises are the work of President Roosevelt's 1936 Committee to examine the whole machinery of the Government of the United States, and the organization of the Tennessee Valley Authority.

It is interesting to note that in 1918 Sidney Webb, then Professor of Public Administration in the University of London, gave a series of addresses on the function of management to a group of factory managers. He then stressed the point that good management is largely a matter of good manners.

It is said that the successes of some of the great Commanders in the Second World War, including Generals Eisenhower and Montgomery, were due in some measure to their employment of the principles of scientific management. Those who are interested in the development of management thought in Great Britain might consult the report on the subject, prepared for the British Management Council by Col. Urwick in 1938. (Available from the library of the British Institute of Management.)

Definitions

Confusion often arises from the nomenclature employed in the sciences, particularly in those such as psychology, which are concerned with human relationships. It may therefore be helpful to set down a number of definitions which are acceptable to the author, at any rate as far as this paper is concerned:—

Management.

1. All activities involving responsibility for the work of others (Ministry of Education pamphlet).

2. The art of directing human activities. (M. G. Frost.)

3. The scientific selection, control and disposition of methods, money, men, materials, machinery, maintenance, manufacturing, marketing, and measurement. (J. E. Walters.)

4. The scientific control of men to produce required results. (Consensus of opinions.)

Administration.

The organization and operation of methods and systems in order to carry out the detailed directions of a higher authority.

N.B.—It is here suggested that the prime difference between management and administration is that management is principally concerned with men, while administration is chiefly concerned with method. Furthermore, management, is generally dynamic and is allowed a considerable amount of freedom in carrying out the policy of the enterprise, whilst administration is, to a much greater extent, a matter of rules. One *manages* a factory but *administers* a pension scheme.

Scientific Management.

1. In the sense in which it is employed in connexion with the work of Taylor and Gilbreth, it means the analysis and subdivision of work, particularly individual tasks, and the discovery by means of time and motion study of the most economical method of doing the work.

2. In the wider sense in which the word is now generally used, it means the employment of research and the application of scientific principle and objective reasoning to solve the problems of controlling, guiding, encouraging, and leading groups of men to achieve desired results with the greatest economy and efficiency.

Management and Administration

It may be useful to offer some additional comments on the differences between management and administration.

As Urwick states in "A Short Survey of Industrial Management" (1949a), it has been assumed that there are two separate techniques and two different problems, business management and public administration. The principles of human organization, however, remain the same in the industrial enterprise and the municipal authority. He points out that private industry, being free to experiment, has greatly advanced the technique of management. On the other hand, the public departments and municipal authorities, particularly the larger ones, can teach much

regarding the long-period government of large-scale undertakings. Government and management are, in essence, the same. Both activities, Urwick asserts, are directed to the arrangement of a human system of co-operation for certain purposes. He says:—

> "In each case, a policy has to be discussed, determined, and administered. In each case, employees have to be engaged, expenditure has to be controlled; the acid test is whether results are secured in line with the policy on a scale to justify the expenditure. Those responsible have in each case to deal primarily with human beings in various relationships, with competing governments or business undertakings, with constituents or customers, with officials, whether public or private, with workers. And the reactions of human beings are broadly similar, whatever their occupation."

The terms "management" and "administration" however, are often employed as if they both meant exactly the same thing. Unfortunately, there is a greater confusion in the terminology of the new art and science of management than we find in possibly any other branch of science, except, perhaps psychology. There is an undoubted need, as H. G. Wells claimed, for an authority to determine more exactly the meanings of words in common use, particularly those relating to human conduct and affairs.

In this case, as has been indicated in the preceding paragraph, there would appear to be a fundamental difference between management and administration, though it often goes unrecognized. Management is essentially management of men, flexible, dynamic and purposeful, constantly meeting with changed conditions necessitating changed methods; whereas administration, whilst it must carry out policy, whether stable or not, cannot be said to have the same active and positive aims as management, being more concerned with systems and methods.

"Scientific Management"

As mentioned in the paragraph entitled "Definitions", the term "scientific management", while it is now more generally employed in the broad sense, is often reserved for that aspect of management which deals with the improvement of productivity by the scientific selection, education, training and development of the workman and the improvement of the worker's techniques,

largely by the elimination of wasted effort. In this field, the names most prominent are those of Taylor and Gilbreth in the U.S.A., and their work was enthusiastically received and adopted in that country, but recognized far more slowly here. Time and motion study, which has done so much to improve output, particularly in mass-production, might be said to have been introduced by these experimenters and innovators, both of whom were engineers. They acted on the principle, afterwards developed in such spectacular fashion by Henry Ford, that there is a better way of doing everything.

Much has had to be done to overcome the workers' prejudice against these new methods. The prejudice was not unwarranted, for often time and motion study was introduced by the management in order to speed up the work, without any regard for the human factors involved, and sometimes without reasonable compensation to the worker. The name of Charles Bedaux springs to mind here. As a consultant in scientific management he assisted large numbers of enterprises to increase production and lower costs, but he and his staff often aroused the bitter opposition of workpeople and their organizations, who saw in the stop watch and the movements diagram an attack on their working conditions and on their freedom as individuals.

Scientific methods of job and movement analysis in some industries have achieved astonishing results, but unfortunately they have not been applied to anything like the extent which is possible. The reason for this does not by any means lie entirely at the door of the workman. Scope for the introduction of such methods is very limited in the water industry, but that does not mean that opportunities do not exist.

As with all new developments, particularly those affecting human relations, there has inevitably been a great amount of nonsense talked and written, and, reading the literature on the subject, it is frequently difficult to sift the wheat from the chaff.

Management Theory

It is not easy to summarize the many aspects of management theory, but an attempt may be made to set out in simple form some of the main principles generally accepted. They are, in fact,

plain common sense, but only in recent years have they been enunciated:—

(1) The purpose of the enterprise must be known and understood by everyone engaged in it.
(2) The best methods of carrying out that purpose must be found, and must be constantly reviewed.
(3) The basis of sound method is accurate knowledge ("Know, then do!").
(4) There must be a constant striving after efficiency, and consequent reduction of waste.
(5) The most important of all the factors in industry is the proper use of human labour.
(6) To achieve the maximum of success in the enterprise, every person employed in it must willingly co-operate and give of his best.
(7) To secure this ready co-operation, the conditions of work must be satisfactory, treatment must be fair, there must be promptitude in the settlement of grievances, and each worker should, if possible, have some voice in the conduct of the enterprise.
(8) No one can directly control or guide an indefinite number of workers effectively. The optimum number varies, and is usually between 5 and 50. There must be a single executive head or leader, and he must control through a series of lesser leaders who must be trusted, and trustworthy.

Education for Management

Management can never be an exact science, as the Past-President, Mr. K. L. Forster, stated in 1952. Its general principles, however, can be collected, enunciated, taught and tested, like those of other technical and vocational studies. Evidence of this is the existence of a number of educational bodies, principally technical colleges, which offer courses of study, in addition to the universities, which award degrees in commerce. It is, of course, not necessary to state that learning and study cannot by themselves produce the capable manager. Certain basic qualities are needed, and the careful selection of candidates is necessary if the time and effort spent on management training are not to be wasted.

The Ministry of Education set up in October, 1945, a Committee consisting of representatives of many engineering and management bodies, to consider the co-ordination of management studies, and their report was published in 1947 as a pamphlet entitled "Education for Management." The recommendations included the following:—

"5. That all management professional institutions should adopt a common curriculum for the intermediate course and that technical professional institutions should adapt any management requirements in their syllabuses to this common curriculum.

"6. That the intermediate course should consist of three parts: an introduction to management, the 'background' subjects, and the 'tool' subjects.

"7. That there should be two types of final course, one for those who wish to qualify for management in some specialized field, the other for those who wish to qualify in general management.

"8. That the curriculum for the final course in each specialized field should be prescribed in large part by the appropriate management professional institution and that the curriculum for the final course in general management should be prescribed by the appropriate national authority, but that final courses of both types should contain certain common elements.

"16. That an Advisory Council on Education for Management should, from the outset, be associated with the proposed Central Institute of Management.

"17. That a commission of enquiry should visit the United States of America to investigate and to report on the facilities for education in management in that country as compared with those provided in Great Britain."

Education for management should comprise:—

"(a) An adequate standard of general education as the foundation of subsequent training.

"(b) Certain 'background' subjects, a knowledge of which provides a basis for the study of management in any particular field. In business, for example, these include the History and Structure of Industry and Commerce, Economics, Industrial and Commercial Law, and Psychology.

"(c) Certain 'tool' subjects with which the manager should be conversant. He need not himself be highly skilled in their use, but he should have a sufficient appreciation of their principles, processes and application to be able to direct skilled assistance effectively. Among such subjects are Accounting, Statistical Method, Production Methods, Work Analysis and Incen-

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tives, Costing and Financial Control, and Office Organization and Method.

"(d) Finally, there are the 'management' subjects themselves. They include the evolution of management, the six aspects of management listed by Fayol (see above) and the major activities of business, with the management methods applicable to each. These activities are Production, Distribution, Finance, Development, Purchasing, Transport, and Personnel Management."

Skill in management involves a number of sectional skills, including:—

"(a) Financial Management, including economic forecasting, accounting, costing, statistical control, budgetary control, insurance, and actuarial work.

"(b) Production Management, including work analysis, scheduling, routing, planning, quality control, and time and methods study.

"(c) Development Management, including research into materials, machines and processing, pure and applied, the whole field of application of the physical sciences to industrial processes, laboratories, experimental plants, etc., and the relation between design, consumer demand, and production.

"(d) Distribution Management, including marketing, merchandizing, consumer research, advertising, sales management and export.

"(e) Purchasing Management, including tendering, buying, contract work, store-keeping, and stock control.

"(f) Transport Management, including transportation by road, rail, water, and air; packing, and warehousing.

"(g) Maintenance Management, including upkeep of buildings, plant, equipment, and estate work.

"(h) Personnel Management, including selection, employment, placement, training, transfer, promotion, retirement, industrial relations, medical and welfare services, and safety.

"(i) Office Management, including all arrangements for communication and record, planning, and control of offices".

Specialists in the above sections have in most instances their own professional institutions. In addition, there is the widely embracing section known as General Management, which, con-

sidered either as business or government administration, is the concern of more than one professional body.

The professional organizations fall into two main groups:—

"(a) Technical Professional Institutions, i.e. those offering a professional qualification in a branch of knowledge having direct application to industry and commerce, e.g. Accountants', Engineers', Secretaries'. Such institutions tend now to include some management instruction in their syllabuses.

"(b) Management Professional Institutions, i.e. those offering a professional qualification in some aspect of management, e.g. Personnel Managers', Sales Managers', and Works Managers' ".

The report recommended that the intermediate syllabus should have three parts:—

Part A. Introductory Subjects.

1. The evolution of modern industrial organization.
2. The nature of management.

Part B. "Background" Subjects.

1. The economic aspects of industry and commerce.
2. The legal aspects of industry and commerce.
3. The psychological aspects of industry and commerce.

Part C. "Tool" Subjects.

1. Financial accounting and cost accounting.
2. Statistical method.
3. Work measurement and incentives.
4. Office organization and methods.

It was suggested that the course leading to the final examination for management in a specialized field, should consist of the following subjects:—

1-6. Syllabuses prescribed by the appropriate management professional institution.
7. Management—Principles. (See Syllabus for Final Examination in General Management, items (7) and (8).)
8. Management—Practice. (See Syllabus for Final Examination in General Management, items (7) and (8).)

Similarly, the course leading to the final examination in general management should also consist of eight subjects, as follows:—

1. Factory management.
2. Distribution.
3. Development and design.
4. Purchasing, storekeeping, and transportation.
5. Personnel management.
6. Higher business control.
7. Management—Principles.
8. Management—Practice.

Obviously, the courses are designed more for those who will be engaged in factory management than for water engineers and managers, but the differences between requirements in industry generally, and in the water industry, are largely those of emphasis. Detailed syllabuses are given in the appendixes to this pamphlet, and they will repay study.

Management in the U. S. A.

The Ministry of Education pamphlet states, in Appendix D, p. 32 ". . . the United States have a wealth of equipment, of experience, and of trained personnel in this field (Business Management), to which there is no parallel in Great Britain". For over 30 years, the U.S.A. have provided increasing facilities for training in management techniques, and there is no doubt that the stupendous increases in American productivity have, to a considerable extent, been the result of this. The tendency in this country was at first mildly to scoff at the diplomas obtainable in the United States in business subjects; but we are now ready to study and adopt, in many cases, American methods, and our universities and technical colleges are giving an increasingly important place to such studies.

Anglo-American Council for Productivity

The Anglo-American Council for Productivity published in 1951 the report of a visit to the U.S.A. in that year of a specialist team concerned with education for management. The leader was Col. L. Urwick, who was for some years Director of the International Labour Office at Geneva, and who is now a business efficiency consultant. The deputy leader was Sir Hugh Chance, a prominent Midlands industrialist and a supporter of industrial education. Included in their findings are the following:—

(1) *Close connexion between productivity, management, and*

education.—Practically every Productivity Team which has visited the U.S. is agreed that productivity per man year is higher than in Britain. They attribute this mainly to two factors. First, there is a climate of opinion which regards maximum effort by every individual as the primary guarantee not only of material standards but of the way of life of a free society. Second, there is a quality in management, inspired by this climate of opinion, and stimulated by the American system of higher education in general, and in particular, by that part of it which is devoted to administrative studies.

(8) *Liaison between business and the universities*.—Business and the universities work very closely together, and this is a major factor in the success of training for administration. The points of contact are many, and everywhere there is evidence of mutual understanding and helpfulness. There is also close co-operation between the trade unions and the universities, which run courses for their officers.

(9) *Executive development*.—Realizing that education is a continuing process, American business plans ahead to train executives who can succeed to positions of responsibility. Many undertakings, both large and small, have carefully-planned executive development schemes. Universities provide advanced training programmes for established executives, and these are proving most successful.

(11) *Emphasis on human relations*.—Both in the universities, and more particularly in business itself, there is a dominant emphasis on the importance of human relations and the techniques of communications.

They conclude that ". . . American experience has shown that productivity and education for management are closely related".

Management Training

A valuable paper by H. G. Nelson, deputy managing director of a large electrical manufacturing firm, read before the Institution of Mechanical Engineers in 1950, reviews some of the facilities for management training now available in this country, under the headings:—

Education (in reference to courses).

Practice (in reference to engineering apprenticeships).

Experience (in reference to interdepartmental experience gained after apprenticeship, and to the exchange of experience in discussions on management problems at professional institutions).

He employs the term "management" to connote anything from top-management to junior-supervision.

He deals in the paper with the provision of facilities for training by individual firms, education in leadership, selection of personnel for management training, introduction to responsibility. He sets out in an appendix a list of the educational courses available for foremen, and what he calls junior executives and senior executives. He also gives the following short list of professional institutions concerned in one way or another with management (not mentioning however, the Institute of Public Administration):—

The British Institute of Management, Incorporated Sales Managers' Association, Institute of Costs and Works Accountants, Institute of Industrial Administration, Institute of Personnel Management, Office Management Association, Purchasing Officers' Association, Works Management Association, British Association for Commercial and Industrial Education.

Professional Management Associations

The British Institute of Management was set up following the publication in 1946 of the report entitled "A Central Institute of Management", published by a Committee appointed by the President of the Board of Trade in November 1945. It was envisaged by the report that the Institute would comprise three main elements:—

(a) Management associations,

(b) Industrial and commercial firms,

(c) Individuals, trade associations, and trade unions as affiliated bodies.

To-day, the British Institute of Management (the B.I.M.), which receives Government support and financial assistance, provides a library and information service, develops management education and training on a national scale, assists the Ministry

of Education in operating a scheme for part-time management studies in technical and commercial colleges, publishes handbooks and papers, organizes conferences, carries out research, and co-ordinates activities in the management field.

Sharing its headquarters, Management House, 8 Hill Street, W.1, are a number of allied organizations, including the Institute of Industrial Administration, the Institute of Personnel Management, the Office Management Association, the British Association for Commercial and Industrial Education, the Association of Supervisors' Discussion Groups, and Management Publications, Ltd., which publishes several management journals. It also represents Great Britain on the Comité international de l'Organisation scientifique (C.I.O.S.), which held its last conference at Brussels in 1951, and will hold its next in 1954 at Sao Paulo, Brazil.

The Institute of Industrial Administration, now the professional branch of the British Institute of Management, was founded in 1921, the Institution of Production Engineers being formed in the same year. The Works Management Association and the Purchasing Officers' Association were set up in 1931, and the Confederation of Management Associations in 1934. With the formation of the Works Management Association and the Confederation of Management Associations the author had the good fortune to be associated. The Office Management Association was formed at about this time; its parent body, the Office Machinery Users' Association, dated from 1915, just after the formation of the Institute of Labour Management, but is no longer in existence.

The Sales Managers' Association was founded in 1911, and its incorporation took place ten years later. It is interesting to observe that the importance of training the sales manager was thus recognized before the much greater importance of training the manager of men.

There are many other bodies connected with the management profession, such as, for example, the Management Research Groups set up first in 1927 by Seebohm Rowntree, but a full list would be out of place here. In Urwick's report on the Development of Scientific Management (1938) is given a most informative table of agencies and institutions concerned with manage-

ment. Though this is now somewhat out-of-date, it gives a much clearer picture than is possible by setting out a list of these organizations.

Principal Functions of Management

The principal functions of management include:—

(a) The assimilation of policy and its transmission to subordinates; (b) Production, purchasing, distribution and sales; (c) Planning and co-ordination of all activities; (d) Research and design; (e) Development and extensions; (f) Maintenance of works and plant; (g) Administration and office organization; (h) Finance; (i) Accounting and audit; (j) Cost accounting, examination and control of overheads; (k) Handling of cash; (l) Insurance; (m) Stock control; (n) Transport and power; (o) Engagement of consultants and specialists; (p) Public relations and publicity; (q) Relations with Government Departments and Local Authorities; (r) Relations with employer organizations; (s) Legal matters and industrial law; (t) Assessment of efficiency; (u) Personnel management (see below).

Some, but not many, of these functions or aspects of management have, of course, little or no relation to the control of water undertakings.

Personnel Management

During the past 40 years, many of the basic problems of production and, to a lesser extent, those of distribution, have been solved, or reduced to generally accepted rules. The problems of human relationships, however, are much more intractable, largely because they are only partially understood. This statement applies to every level of human organization, including that of the individual enterprise. Human beings are complex and largely unpredictable organisms which do not obey mechanistic laws. There are rules of human conduct, however, which are gradually being formulated as a result of the work of the psychologist and the sociologist. Perhaps the two principal human problems in industry are the avoidance (or settlement) of disputes, and the economical employment of labour.

In respect of the first, the water industry has an enviable rec-

ord, resulting largely from the work of the Joint Industrial Councils, the first of which was set up in 1919. As to the latter, it is doubtful whether the water industry can claim to be superior in any way to other industries. Personnel management, therefore, is one of the principal functions, and perhaps the principal function of management, which is in this paper intended to mean predominantly the control of men.

In industry, the importance of personnel management is now so widely recognized that it is usual in large undertakings to employ personnel managers whose sole duty it is to handle, under the general manager's guidance, all personal relationships in the factory or business. Thus, in large enterprises the works manager is now tending to disappear, and his place is being taken by two officials, the personnel manager and the production manager.

Some of the chief aspects of personnel management include:—

(a) Leadership and inculcation of team spirit; (b) Selection, recruitment, training, promotion, and records of staff and workpeople; (c) Employment of juveniles; (d) Wages and salaries; (e) Incentives and payment by results; (f) Welfare, hygiene, health and safety of workpeople; (g) Conditions of employment; (h) Personal problems and grievances; (i) Discipline; (j) Labour turnover; (k) National Insurance; (l) Pensions; (m) Joint consultation and negotiations with trades unions; (n) Information.

Qualities Desirable in the Manager

One of the most serious of all the shortages from which we suffer to-day is undoubtedly the scarcity common to all fields. It is of men possessing the principal qualifications for management, including those innate in the individual or developed by education and social circumstances, as well as special training, education and experience in the control of men. Some of the reasons for this scarcity become evident when one examines a list of the qualities and attributes which it is desirable that the manager should possess. They include:—Capacity for leadership; character and integrity; good health; personality; education; training; experience; adaptability; understanding; patience; energy; reasonableness; approachableness; sympathy; firmness; sense of

justice; ability to take responsibility; imagination; initiative; orderliness; good judgment.

Most of these attributes are capable of being developed, regardless of George Bernard Shaw's dictum about the importance of selecting the right parents. The list contains some apparent contradictions, but possession of the last-mentioned attribute, "Good judgment", will resolve these. The first item, "Leadership", is generally admitted to be all-important, and, although this is given premier place in the list, it includes, or is derived from many of the other items listed. Opportunities for leadership and the assumption of responsibility should be provided, and taken, in school, college, and industry, leadership being an art whose acquirement takes a long time and should therefore be encouraged at an early age.

Though the list was compiled with general or higher management in mind, it applies to a very large degree to all those with managerial responsibilities, including supervisors or foremen, whose art or skill is now often referred to as foremanship. For many of us, the realization of our shortcomings when judged against the list is salutary, but somewhat humbling, and the difficulty of achieving what Stephen Potter might call "managership" becomes fully apparent. Difficulties, however, act as a spur to the engineer, and should have the same effect on the would-be manager.

The Institution and Management

It is hoped that this paper will encourage others to write papers on some of the many aspects of management touched on here. It would be helpful if the Study Group from time to time were to produce papers or reports of direct assistance to the members, particularly the junior engineers whose careers have still to be made.

The Institution, not having its own examinations, cannot apply any tests of capacity for management. The Institutions of Mechanical and Electrical Engineers, however, have now included as alternative subjects several connected with management. It is to be hoped that our Institution's parent body, the Institution of Civil Engineers, will soon do the same.

The professional engineering institutions at present require

academic qualifications and practical engineering experience. In spite of the exception of the Institutions of Mechanical and Electrical Engineers, they neglect almost entirely the management factor, which is of importance in some degree to the engineer, and is of paramount importance to him when he takes over control of industrial enterprises and public utilities.

Summary

This paper is submitted as an introduction to management, regarded as a separate science: the science of controlling men to achieve a common aim with maximum efficiency. It makes reference to the history and development of management in industry generally, and in the water industry in particular. Some of the functions of the manager, and particularly of the engineer and manager, are mentioned, as well as the present position of management education and training. Since most water engineers must accept managerial responsibility sooner or later, it is suggested that they should deliberately set out to acquire training and experience as managers.

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RE-CHLORINATION IN THE HARTFORD DISTRIBUTION SYSTEM

BY ALEXANDER J. MINKUS*

[*Read at Chemists' Session, Nov. 21, 1957.*]

This paper will describe how excessive coliform concentrations in the Hartford distribution system were reduced to an acceptable limit by a second automatic application of chlorine. Control of the dose was made automatic (without a flow-measuring device) by the use of a chlorine-residual indicator.

In brief, the Hartford water system consists of several surface-water storage reservoirs, which supply the treatment works comprising an aerator, 18 slow-sand filters, storage basins, and chlorinators. The filter plant is on the west side of the Hartford metropolitan area, and the distribution system lies mainly in the sector defined by the northeast and southeast lines, extending from the filter plant as a center. The remotest part of the distribution system is about 13 miles from the filters.

Ever since their construction in 1922 the slow-sand filters have produced an effluent meeting the standards of the Public Health Service or its predecessors. Prior to 1941 this good bacteriological condition was obtained without the benefit of chlorine, and in several of the subsequent years it required only 0.2 ppm of combined chlorine to maintain that condition. During all this time the water in the distribution system was of satisfactory bacteriological quality. There were occasional bad samples, but considered on the whole, the distribution system met the Government standards month after month.

However, starting in 1946 the bacteriological character of the distribution system took a turn for the worse. High coliform concentrations became so numerous in the summer months and early autumn that the system no longer met the Government standards, much to everybody's embarrassment. Peculiarly enough, the filter effluent after chlorination was consistently free of coliforms. We attempted to attribute the presence of these

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organisms to three factors—namely, the stirring of sediments by the high-velocity flows of the summer, the higher temperature of the water, and the tremendous expansion of the distribution system.

None of these explanations, however, would stand up to rigorous analysis. The temperature of the water in the summer months was no higher now than it had been prior to 1946. The increase in water consumption for the summer was no bigger proportionally than in other years. The third theory, the expansion of the distribution system, did not seem logical either. Although there was an unprecedented growth of the distribution system starting in 1945, most of it was on the periphery of the system, plus a small percentage of new transmission mains extending into the heart of the distribution grid. On the other hand, the poor bacteriological samples were being found in the older parts of the district, upstream of the new pipes.

Also suspect was the method employed to sterilize new pipes, yet this seems adequate. All newly laid pipes are dosed with 50 ppm of chlorine. Those under 16 in. are treated by attaching enough pellets of hypochlorite to each length of pipe to produce a concentration of 50 ppm of chlorine when they are dissolved. Upon completion the main is filled with water and allowed to stand 24 to 48 hours before it is flushed clear of excess chlorine. Pipes over 16 in. are treated by first establishing a known flow of water, which is measured by a portable 3-inch disc meter, connected with 3-inch rubber hose to a corporation at one end of the main. At the other end a portable gasoline-driven hypochlorinator injects the solution through a corporation at a rate calculated to produce a concentration of 50 ppm for the established rate of flow. When the chlorinated water appears at the meter, the flow is stopped and the water remains in the pipe at least 24 hours before it is flushed out.

Notwithstanding these precautions and the practically sterile condition of the filter effluent, the coliforms continued to appear in the distribution system. The first step to better the condition was the obvious one of increasing the chlorine residual in the filter-plant effluent. The increase was gradual; it took from 1946 to 1955 to raise the peak residual values from 0.3 ppm to 2.0 ppm. The corresponding annual averages were 0.2 ppm to

1.0 ppm. The marked difference between the peak and average figures is the result of carrying higher residuals in the summer months only. It was our hope that the higher residual would carry a trace of chlorine into the far reaches of the system and eliminate the coliforms. While the residual was below 1.5 ppm there were numerous complaints, limited to aspersions on the taste of the water only, but when the residual approached 2.0 ppm red-water complaints began to pour in from the residents close to the treatment works. We lost our courage and cut back to 1.0 ppm of chlorine.

Even though we had by that time maintained a residual of over 1.0 ppm during the summer months of 3 years, and about 2.0 ppm for two weeks, there was not a trace of chlorine in that part of the system where the coliforms were being found. It appeared to us then that the logical thing to do was to apply chlorine closer to the points where it was needed, rather than over-dose a section which was already in an excellent bacteriological condition.

A likely spot for such an application point existed at a concrete storage reservoir, located in the southern section of the distribution system and about 4 miles from the filter plant. This reservoir actually consists of two rectangular covered basins, each of 5-mil gal capacity, 26.5 ft deep, located on high ground known as Cedar Mountain. The overflow level is slightly above the hydraulic grade line during low rates of flow, and the drawdown at peak rates is about 8 or 10 ft, which is equivalent to about 3 mil gal of water. The rate of flow from the basins sometimes reaches a rate of 10 mgd. Each basin has an individual 30-inch pipe to serve as both influent and effluent line, and these two 30-inch lines branch from a 42-inch pipe, which is an offshoot of the distribution grid.

Because the Cedar Mountain Reservoir was designed primarily to improve pressures in the system, there was no need at that time to install meters of any sort in the 30-inch mains, nor were there any bypasses or check valves. This is by no means an ideal site for a chlorine plant, but it was all that was available. Its strong point was that there was sufficient space in the superstructure to house the chlorine equipment.

The problems which had to be solved to adapt this reservoir to chlorination were therefore these:

First, chlorine application had to be limited to the effluent only of the reservoir, so that the reaction time would be a minimum and a relatively higher chlorine residual would be carried into the system.

Second, the dose had to be made proportional to a varying flow without the use of meters, for the problem did not warrant the large expenditure that two 30-inch meters would entail, nor did it seem advisable to shut off the reservoir, break into the piping, and insert a couple of differential-producing devices. Furthermore, a fairly close control of the chlorine dose was necessary, because the water had been dosed once before at the filters and its chlorine demand had been largely satisfied. Slight additions of chlorine now caused relatively large changes in the residual.

As the Wallace & Tiernan Co. offered equipment which could overcome these problems, we proceeded with the installation and got it into operation early in August, 1956. The major elements of the plant are: a chlorine-residual recorder; an electrical device, known as an interrupter, which is essentially the dosage controller; and an automatic solution-type vacuum chlorinator.

The sequence of operations in the plant are as follows: A hundred feet below the point where the two 30-inch pipe lines are connected to the 42-inch main, a continuous sample of chlorinated water is taken at a corporation and pumped into the residual recorder, which measures the chlorine content by the amperometric method and records the results on a revolving chart. For the intricacies of this device I refer you to Wallace & Tiernan literature, but stated briefly, the recorder plays its part by rotating several cams in proportion to the movements of the recording pen. The cams in turn open and close micro-switches. Some of the switches are to initiate a signal for an increase in chlorine residual, and the others for a decrease. Within the desired range there is no signal.

The signals from the micro-switches are transmitted to the interrupter, which has the function of converting the simple "on

and off" signals to ones which have variable frequency, duration, and speed. Properly adjusted, this device serves as a damper and prevents hunting around the required setting.

The now complex signal positions a motorized valve in variable steps. The motorized valve bleeds air from under a pneumatic piston, which by its motion varies the size of the V-notch orifice in the Wallace & Tiernan chlorinator. The size of the orifice determines the chlorine feed.

The whole scheme of operation consists of making a measurement and then adjusting slightly toward a predetermined point. For instance, if the residual in the water is below a selected value, the interrupter makes a series of timed corrections, which tend to raise the chlorine feed by small increments until the residual is the one desired; then the signals stop and there is no further change in the position of the chlorinator feed. If the adjustments overshoot the mark, a reverse action takes place. This is probably a good example of automation applied to our industry.

The problem of stopping chlorination entirely, when the flow of water was into the basins, was handled by installing a so-called flow switch in one of the 30-inch mains. This switch has the function of making an electrical contact when the water flows out of the reservoir, and breaks the contact when there is no flow, or when it is toward the reservoir. Most of the difficulties experienced on this job can be attributed to this switch. At the time of installation we could find only two manufacturers in the United States who made the desired type of switch. Many switches of this general nature are available, but they are for small pipes in the range of 1¼ in. to 4 in. The one we purchased was impossible to install in a corporation under pressure and, when installed by shutting the main down, was not quite sensitive enough for the intended purpose. After considerable experimentation and some modifications it was made to behave satisfactorily, and there has been no trouble with it during the past year.

When this flow switch signals the plant to go into operation, the discharge from the chlorinator is put into only one of the 30-inch mains, and this overdosed water mixes with the water from the adjacent pipe a few feet from the point of appli-

cation. A hundred feet downstream from here the composite water is sampled by the residual recorder, which initiates any corrective action that may be necessary. This is by no means an ideal arrangement, for the mixing of the two waters is probably incomplete, and a non-representative sample sets off an undesirable chain of signals.

These sub-ideal conditions should therefore be kept in mind when considering the results of operation to date. We have been attempting to keep the residual in the range 0.8 to 1.2 ppm (of free chlorine), and we succeed for about 6 or 7 hours of the morning and early afternoon, when the water is flowing out of the reservoir at a significant rate. In the late afternoon and early evening, when water flow stops or reverses several times, the variations are sometimes from 0.3 to 2.0 ppm. The low figure shows that some water has trickled out of the reservoir so slowly that the flow switch was not activated, and the high figure probably represents a slug of water which has been dosed several times as it oscillated back and forth past the chlorine-application point. These wide fluctuations are not alarming, because it is evident that when the water has reached the distribution system, there has been enough mixing to iron them out, and the residual is very close to 1.0 ppm.

The important question, "Has this installation reduced the coliform content in the system?", can be answered "Yes". In Table 1 are listed the percentages of all positive 10-ml portions derived from samples collected in the distribution system for the years 1943 through October of 1957.

As the samples are collected from 37 sampling points, and the portions total about 10,000 per year, they should be a good indication of the bacteriological quality of the water. These figures show that in the ten years prior to the installation of the Cedar Mountain chlorinator the 10-ml portions averaged 4.2% positive, whereas in the two years of chlorination in the distribution system, 1956 and 1957, the corresponding average is 1.6%. Probably of more significance is the fact that in 1956 and 1957 the U.S. Public Health Standards were met every single month, while in the ten previous years seven of them had one or more months which were sub-standard.

A further benefit of the Cedar Mountain installation is the

reduction in the chlorine residual which can be maintained successfully in the filter effluent. The two large mains which carry water in the general direction of Cedar Mountain now have a residual of 0.5 ppm, and there are practically no complaints of chlorinous tastes in the vicinity of the filter plant.

TABLE 1.—COLIFORM CONTENT OF DISTRIBUTION-SYSTEM WATER

Year	Per cent of 10-ml portions positive	Sub-standard months
1943	1.0	0
1944	0.2	0
1945	1.3	0
1946	3.9	Aug.
1947	3.1	July
1948	4.9	June, Sept., Oct.
1949	4.1	0
1950	6.9	July, Aug., Oct.
1951	3.7	Aug.
1952	3.3	Sept.
1953	5.8	0
1954	2.3	Aug.
1955	4.3	0
Chlorination in the distribution system started August 1956		
1956	1.6	0
1957 (to November)	1.5	0

Measurements to determine the extent of penetration of chlorine into the distribution system show that this line has been extended about 3 miles farther downstream from Cedar Mountain.

In summary it can be said that a chlorine installation, located in the middle of a distribution system and controlled solely by the residual present in the water, has effected a marked reduction in the bacterial content of the distributed water and has permitted a lower chlorine concentration to be maintained in the vicinity of the treatment works.

MODERNIZING THE WATER DEPARTMENT, FIRE DISTRICT NO. 1, SOUTH HADLEY, MASS.

BY GEORGE H. McDONNELL*

[*Read November 21, 1957.*]

The town of South Hadley is located on the Connecticut River upstream of Chicopee and Springfield (see Fig. 1). It is the home of Mt. Holyoke College and also contains a half-dozen paper manufacturing and processing firms. In general, the town is a college town and a residential community for the more industrialized areas of Holyoke and Chicopee, as well as nearby Westover Field.

Water supply and fire service are provided the community by two fire districts. In this paper we are concerned with Fire District No. 1, which covers the southerly and larger portions of South Hadley (see Fig. 2).

Prior to the expansion program started in 1949, the sources of water supply were two in number—namely, Buttery Brook and Leaping Well Reservoirs. Both were located within the limits of the Fire District, and, at the time of their abandonment, the areas surrounding the reservoirs were rapidly expanding with housing-development construction.

Buttery Brook Reservoir was constructed as the original Fire District installation in 1872. It had been enlarged at various times, the last being in 1941. The drainage area is about 300 acres, the greatest part being in the city of Chicopee, and upon this part there resides a large population. The 4½-acre pond of the Buttery Brook Reservoir contained about 9 mil gal and had a safe yield of about 175,000 gal per day.

Leaping Well Reservoir was constructed in 1892 and has a drainage area of about 400 acres. The pond area is about 9 acres and contains about 30 mil gal, with a safe yield of 320,000 gal per day.

The water from these two reservoirs was pumped into the distribution mains, the excess water being stored in two stand-

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pipes, one located behind Leaping Well Reservoir and the other across the District on North Main St.

The total safe yield from Buttery Brook and Leaping Well Reservoirs was 495,000 gpd. Water consumption by the District in 1948 had been in excess of the computed safe yield, causing a serious shortage and the necessity of restrictions during the late spring, summer and fall months. In fact, restrictions had been in effect during summer periods prior to 1948, when reservoirs had become low in reserve supply.

The last major improvement made to the water supply and distribution system took place in 1929, when meters were installed and the hydraulic grade of the distribution system was increased by the erection of the first of two water-storage tanks and pumping facilities. In the late thirties and through the war years, the use of water resulted in very low water levels in the reservoirs. In order to extend the available stored water through to fall rainy seasons, it became necessary to put restrictions on the use of water each spring, usually when the reservoirs stopped flowing over the spillways. These restrictions prevented hose use, car washing, and water use for many personal and recreational needs. Following the termination of the war there occurred an upswing in District population and an increase in demand for water. Figures 3 and 4 show that water usage and service installations had increased steadily. Beginning in 1945 the rate of annual installations increased, and within a 10-year period the number of water services had doubled.

In 1949 consideration had been given to the further enlargement of the reservoirs in the District. The small increase in safe yield that could be acquired was negligible in the face of the rapid growth.

A study was made to determine the best method of increasing the available water supply at the source and of improving delivery so that pressure losses in the distribution system would be greatly reduced.

Through the year 1949, the rate for sale of water was based on a $3.25 minimum charge per family per quarter. The Commissioners recognized the fact that with rising costs and the need for expansion of the system, an increase in water rates should be put into effect. The increase should naturally consider

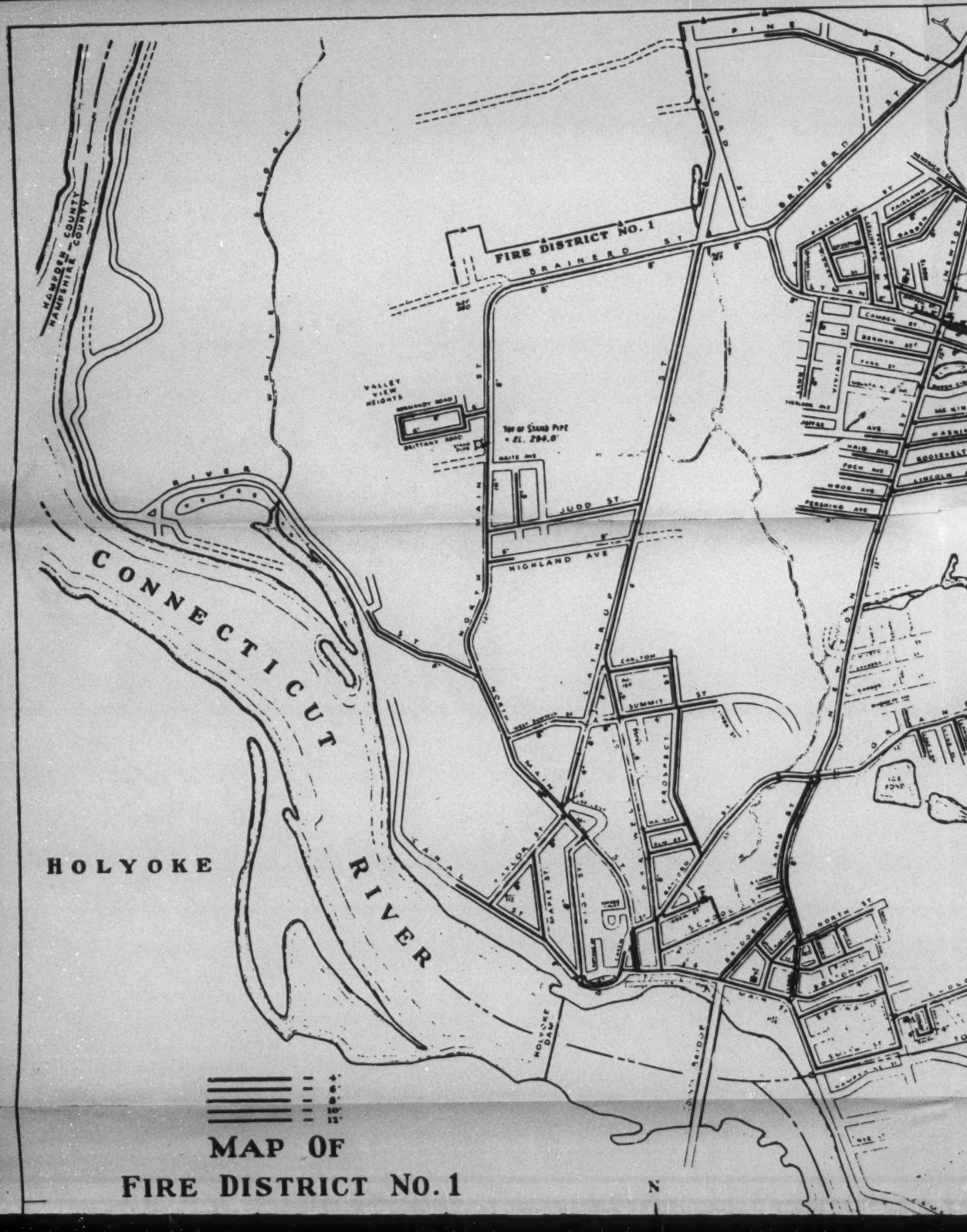
the cost to develop additional sources of water and to improve the distribution system.

Studies were made of the possibility of obtaining water from the three bordering separate water systems—namely, that of Fire District No. 2 in South Hadley, the city of Holyoke, and the city of Chicopee.

Water from Holyoke was eliminated because of insufficiency of supply at that time and problems involved in obtaining water through pipeline construction across the Connecticut River. Also, the Holyoke distribution system was already overtaxed. Fire District No. 2 did not have a sufficient source of supply to meet the needs of District No. 1 and to take care of their own requirements. The city of Chicopee provided the most practical solution insofar as adjacent water supplies were concerned.

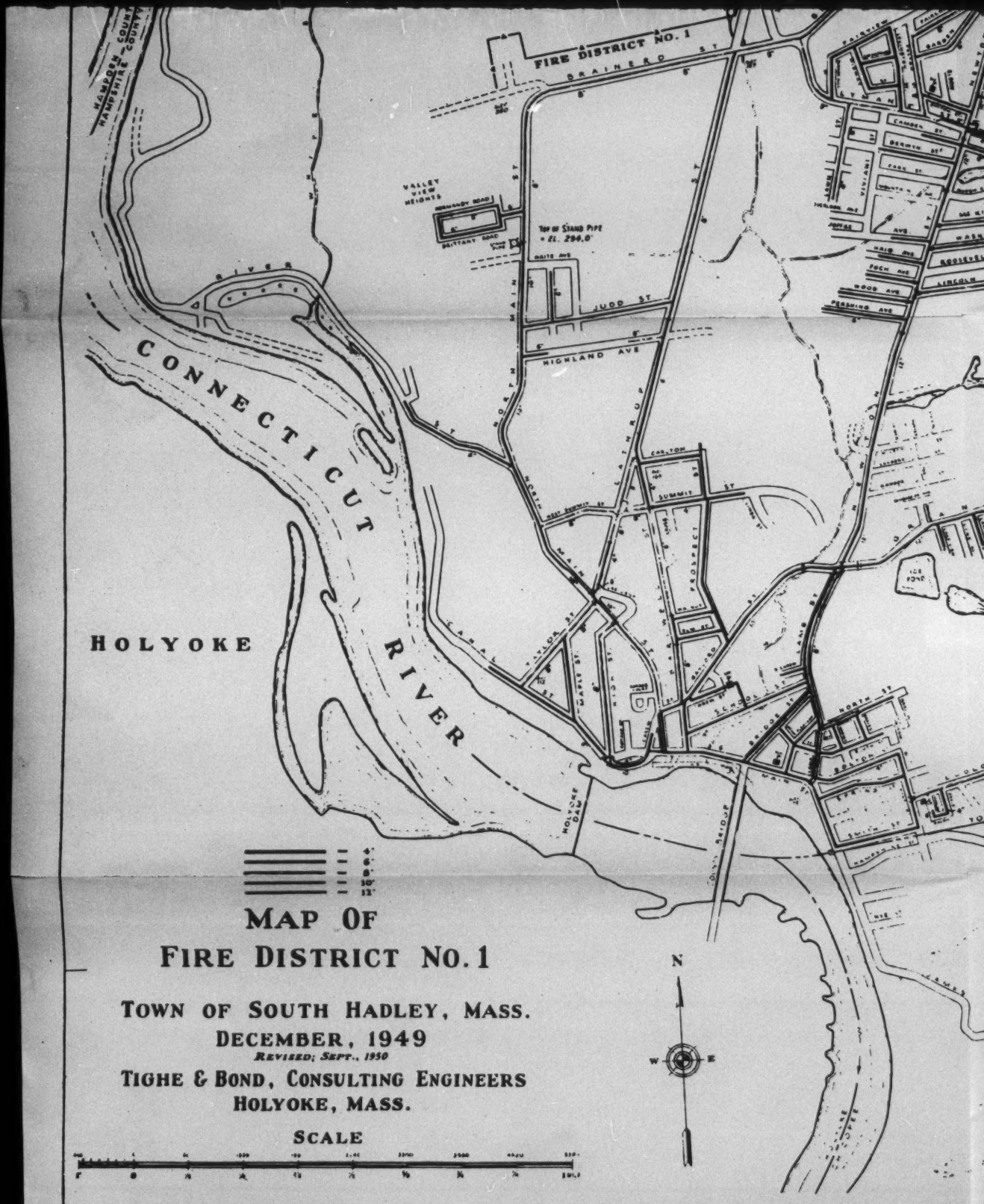
A ground-water supply was also considered. If a water-bearing sand or gravel stratum with sufficient capacity to meet the needs of the Fire District could be located, this solution to the problem of supply would have been the best and least expensive. Consequently, based upon the engineering study conducted in 1949, the District voted a complete and exhaustive study of ground-water potential and appropriated $10,000 for this work. At that time it was also recommended that the rate for water be raised from a minimum of $3.25 per quarter per family to a minimum of $4.25 per quarter per family, and that for all water consumed over 1,500 cu ft, the charge at homes should be at the rate of 20¢ per 100 cu ft. Water sold to industries was to be 11¢ per 100 cu ft. It was decided that the Water Department should be self-supporting, based upon water revenue, and that the services of the Department should be expanded to meet the needs of the growing District. None of the water revenue was to be used to defray any part of the Fire Department costs.

In the year 1949, the total Water Department revenue was $32,559.00 (see Fig. 5). At that time the Department was operated by a superintendent, two maintenance men and an office clerk. The Department owned one vehicle for general maintenance service. In order to have the Department operate efficiently, it was recommended to provide two additional men for maintenance and one additional man, whose sole duty would be to install, replace, repair and service meters. It was recommend-



MAP OF FIRE DISTRICT NO. 1

FIRE DISTRICT NO. 1
GRANBY
MOUNTAIN VIEW ST.
ROAD
LEAPING WELL RESERVOIR
STAND PIPE EL. 307.0'
LYMAN TERRACE
OLD LYMAN ROAD
SOUTH HADLEY
NEW LUDLOW ROAD
HAMPSHIRE COUNTY
HAMPDEN COUNTY
ABBEY ST.
SOUTH HADLEY
CHICOPEE
OLD LUDLOW ROAD
TOWN LINE
BRITTON
BEAUDRY AVE
HIGHWAY
CHICOPEE



MAP OF FIRE DISTRICT NO. 1

TOWN OF SOUTH HADLEY, MASS.

DECEMBER, 1949

REVISED; SEPT., 1950

TIGHE & BOND, CONSULTING ENGINEERS
HOLYOKE, MASS.

SCALE

FIG. 2.

LEAPING WELL RESERVOIR
STAND PIPE
EL. 207.0'
LYMAN TERRACE
OLD LYMAN ROAD
SOUTH HADLEY
NEW LUDLOW ROAD
HAMPSHIRE COUNTY
HAMPDEN COUNTY
ABBEY ST.
SOUTH HADLEY
CHICOPEE
OLD LUDLOW ROAD
CHICOPEE
WESTOVER
FIELD
PROPERTY OF U.S. GOVERNMENT
BRITTON
BEAUDRY AVE
PROSPECT ST

SOUTH
CONNECTICUT
RIVER
WEST SPRINGFIELD
SCALE 1:24000
CONTOUR INTERVAL 10 FEET
ROAD CLASSIFICATION

FIG. 1.

SPRINGFIELD NORTH, MASS

1.

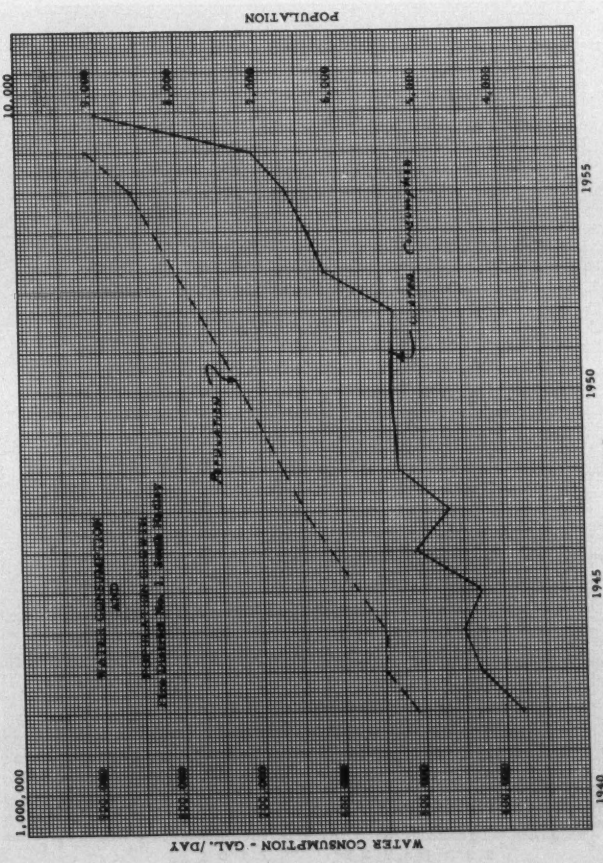

POPULATION
10,000
1,000,000
1940
1945
1950
1955
YEAR
WATER CONSUMPTION - GAL./DAY

FIG. 3.

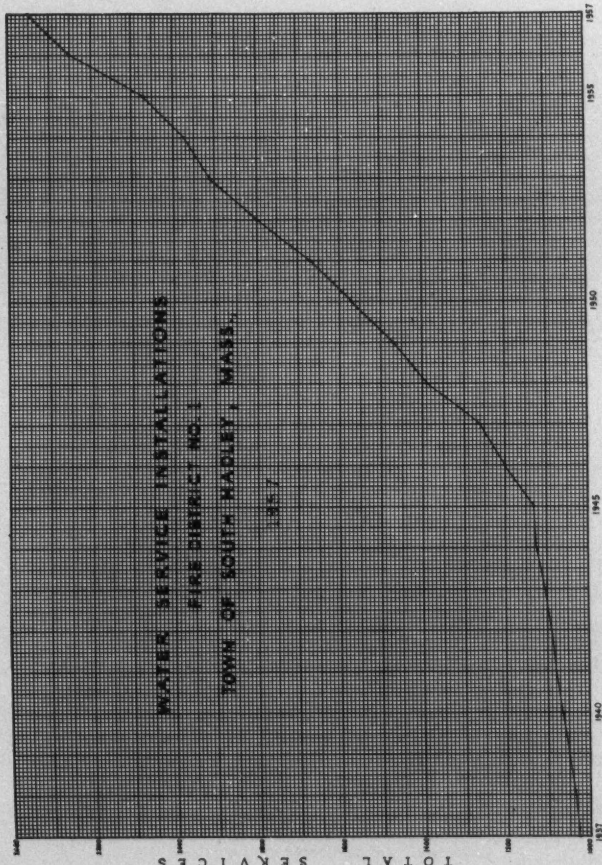

WATER SERVICE INSTALLATIONS
FIRE DISTRICT NO. 1
TOWN OF SOUTH HADLEY, MASS.
1957
TOTAL SERVICES
YEAR
1955
1950
1945
1940
1937

FIG. 4.

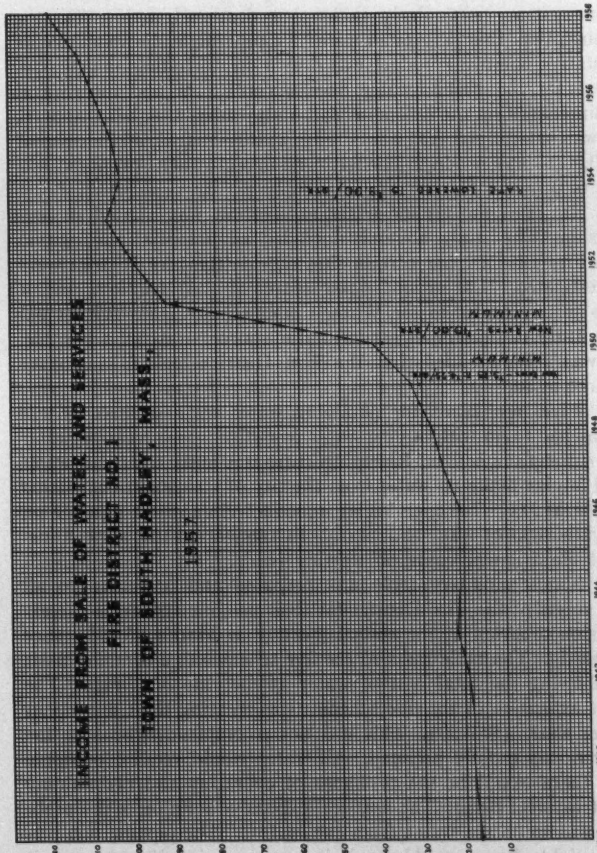

INCOME FROM SALE OF WATER AND SERVICES
FOR DISTRICT NO. 1
TOWN OF SOUTH HADLEY, MASS.
1957
INCOME $ 1,000
YEAR

FIG. 5.

ed that $5,000 yearly be spent on improvements to the distribution system, particularly in looping dead-end mains. On the assumption that a ground-water supply might be available, a tentative operating budget was drawn up, including annual payment for the ground-water development costs and for general maintenance on the recommended improved and higher standard. It was determined that a total of $52,000—that is, an increase of $20,000—was needed. The $4.25 minimum rate as proposed was set to provide this income.

In 1950 the ground-water exploration was carried to conclusion. The study not only included all potential sites within the Fire District, but certain sites outside the Fire District were investigated. The ground-water search proved fruitless, and it was recommended to the Water Commissioners that further expenditure to determine ground-water sources was not advisable. It was recommended that the Fire District look to a surface source of supply.

Five new plans for obtaining water were studied. These plans had to do with buying water from Chicopee; treating water from the Connecticut River; treating the local reservoir water and buying make-up water from the city of Chicopee; connecting to the M.D.C. Chicopee Valley aqueduct via a direct pipeline on private right-of-way, and, lastly, to connect to the same aqueduct via a longer route on existing roads.

A cost-summary table was prepared and presented to all the voters of the Fire District for their use in considering the expansion program at the annual meeting in March of 1951 (See Table 1). The table reduced the five schemes to a common basis in showing the total cost of water at the rate of 1 mgd. The least expensive of the five schemes was treating the Connecticut River water ($89.50). This was not recommended because the source was grossly polluted. All water would require pumping and there would be the problems of operating and maintaining the treatment plant. The next less expensive solution to the problem was to obtain water from the M.D.C. The pipeline via private right-of-way would result in water costing $92.27 per mil gal. By laying the pipelines on existing roads and thus providing more service, and hence increased income, the cost for water would be $94.37 per mil gal. The voters at their meeting, with

TABLE 1

Plan	Description	Construction cost	Ave. annual cost of construction for amortization period	Ave. annual operational cost based on 1950 costs	Cost of water to be purchased (per mg)	Assuming use of 1 mgd		
						Cost of construction	Cost of operation	Total cost of water*
I	Connect to Chicopee at two locations	$111,306.00	$4,560.00	Negligible	$126.00	$12.50	Negligible	$138.50
II	Treat river water	223,056.00	11,242.00	$21,400.00		30.80	$58.70	89.50
III	Treat reservoir water	164,663.00	8,299.00	19,020.00	145.00	40.00	52.20	105.00
IV	Direct pipe to Nash Hill via private right-of-way	391,000.00	16,943.00	500.00	63.00	46.50	1.37	92.27
V	Pipe to Nash Hill via existing roads	420,000.00	18,200.00	500.00	63.00	50.00	1.37	94.37

*Total cost of water is average cost over useful life of installation.

one dissenting vote, agreed to an expansion program of buying water from the M.D.C. and following the public road route.

The newly approved water-expansion program necessitated a revision in the figures for income, in order to result in the Department's becoming entirely supported by its revenue. It was determined that $96,085 would be needed, instead of the $52,000 contemplated the year before, based upon a ground-water source of supply. The breakdown is as follows:

1.	General maintenance (present)	$22,000
	General maintenance (increase)	14,100
2.	Annual improvements to existing systems	5,000
3.	Salary account	4,600
4.	Granby Road Serial Note	2,500
5.	10-year Serial Note for 1950 Water Main Ext.	7,290
6.	Bond issue for 16″ Sup. Line (25-yr issue)	13,600
7.	Bond issue for Second Part of Plan V (15-yr issue)	4,000
8.	Cost of water at Quabbin Supply, Ludlow (365 mg @ $63/mg)	22,995
	Total	$96,085

New water rates were set, providing for a minimum charge per family per quarter of $10 and an allowance per family per quarter of 3,000 cu ft of water for the minimum charge. Water used above the minimum was to be paid for at the rate of $0.30 per 100 cu ft for the second 3,000 cu ft and $0.26 per 100 cu ft for the third 3,000 cu ft. The next 6,000 cu ft would be billed at $0.20 per cu ft, and all water consumed beyond that—that is, above 15,000 cu ft per quarter—would be billed at $0.125 per 100 cu ft. The 10% discount was abolished and all bills were to be paid on time and in full.

During 1951, when the program of expansion was being launched, and the citizens were being billed at the new rate for water, there was considerable reaction and some resentment against the program, even though there had been only one dissenting vote at the well-attended Fire District annual meeting. The Commissioners and the Superintendent handled these complaints in such a manner, with the passing of a two-year period, there was little said against the large increase in rates and the expansion of the system. It is interesting to note that the money actually collected in 1951 under the recommended rates was

$92,069, as compared to the needed estimate of $96,085. The fact was recognized that the District was growing and, though the income was $4,000 below the funds needed to operate the Department as expanded, the sale of additional water to new homes was expected to compensate for this difference. In 1952 this assumption was borne out, when $100,135, or $4,000 in excess of the anticipated needed funds, was collected.

The District undertook an old pipeline replacement program. It was pointed out that such a program was absolutely essential to the continued financial stability of the Water Department. Service must be given to the consumer based upon the relatively high water rate being charged. Over 1/3 of a million dollars was appropriated for the purpose of constructing a 16-in. pipeline from the District to the M.D.C. aqueduct, just easterly of Nash Hill in Ludlow.

During the year 1951, under separate and additional financing, a 12-in. pipeline was laid in the District southerly from the location of the termination of the new proposed 16-in. main, to act as a feeder on what is known as Granby Road. A 10-in. main was laid westerly from the same point.

The 7-mile, 16-in. pipeline to extend from the District to the M.D.C. aqueduct was started and completed in 1952. The contractor had a low bid of $1.18 per lineal foot for the installation of the pipe. The line had a very irregular topography; at the low points there was a static head as high as 90 lb and at one high point nearly zero.

The hydraulic grade of the Quabbin system is approximately 120 ft higher than the hydraulic grade of the District No. 1 system, based upon the water-storage tanks. It was determined that the best solution would be to abandon the two tanks completely and depend entirely upon water supplied by the 16-in. pipeline. In order to protect the District against the loss of water service because of failure of the 16-in. pipeline, an interconnection with Chicopee was installed. This connection provides for two-way flow, and thus either community can benefit in time of an emergency. Consideration has been given to making this connection an automatically operated interconnection, since both systems are operating on the M.D.C. Nash Hill Reservoir supply.

The Buttery Brook supply was completely abandoned, but the Leaping Well Reservoir, pumping facilities and tank have been maintained on a standby basis as an independent emergency supply. It could be referred to as a disaster or a C.D. standby water supply.

The new supply resulted in an increase in pressure of about 50 lb per sq in. This increase was accepted joyfully by those residing in the elevated areas of the District. Where pressures had been 20 psi to 30 psi they became 70 psi to 80 psi.

In the downtown or lower-level sections of the District, the pressure would approach 140 lb. There were many old lead services and some old pipelines that had been giving trouble to the Department prior to the connection of the new Quabbin supply. It was feared that full pressure on the downtown system would result in a tremendous number of service-pipe and main-line breaks. Consequently, pressure regulators were installed on the main lines leading to the downtown area. It was fortunate that the uptown or higher-level area was in the direction of the M.D.C. supply. These regulators provided for maintaining the existing downtown pressure, and a program was developed wherein the pressure downtown was to be raised about 5 lb at a time and held steadily for months at predetermined levels, while any breaks that would occur at that pressure occurred and were repaired. At the present time, the pressure regulators are set to provide within 10 lb of the full pressure downtown. Superintendent Moos expects that in the coming year the pressure regulators will be abandoned entirely.

At the time of the development program, asbestos-cement, concrete and cast iron were considered for pipeline materials. As a result of cost studies and the availability of materials, it was recommended to the Board of Water Commissioners that the new pipeline be constructed of asbestos-cement pipe.

A 16-inch, Class 150, Transite, asbestos-cement pipe constitutes the major dollar-value portion of the development. A meter house located at the upstream end houses the Venturi tube, flow-recording devices and chlorinating equipment. Thirty-one fire hydrants are spaced throughout its length up to the District line. The only fittings in the line are tees for hydrant takeoffs and nine gate valves. Changes in direction and stream

crossings were made by deflecting pipe lengths to form long-radius curves. The design capacity of the line is 3.4 mgd under an available head of about 122 ft.

After the completion of the construction of the 16-in. main a flow test was conducted to determine the coefficient. A section of about 28,000 ft was isolated for test purposes by opening the Chicopee cross-connection and closing a downstream gate on the 16-in. line. Four locations were selected for pressure-reading points and calibrated gages set up there. Recording gages connected at stations 1 and 4 maintained permanent readings for the extreme ends of the test reach, and instantaneous-reading gages were located and read at the intermediate points. Under no-flow conditions, pressure readings at all points established a base elevation to which all other readings were related.

Flows in the line were created by the wasting of water from three downstream hydrants. The total volume of water flowing through the Venturi meter was noted and recorded at regular intervals throughout the tests.

A hydrant was opened and permitted to flow for 15 minutes. Volume readings and pressure readings were noted at two-minute intervals. At the end of this period another hydrant, and later another hydrant, was opened and the flow held stable for 15 minutes each time. In this way a total of five individual test runs were made with velocities ranging from 1.00 to 3.65 ft per sec.

The calculated results from this series of tests indicated that this 16-inch supply line for South Hadley Falls has an average flow coefficient of 148.

During the summer of 1957, though many communities were forced to restrict the use of water because of high rates of demand, no restrictions were required throughout Fire District No. 1. All consumers were allowed to use as much water as they desired for any purpose whatsoever and at any hour of the day they wished to consume the water. Water bills for the summer quarter in excess of $15 were not unusual. Whereas at the beginning of the expansion program there were feelings of dissatisfaction by many property owners over the comparatively high rate for water, the citizens of the District were quite enthusiastic in their remarks in 1957 about having ample water at good

pressure, with no worry about conservation of water or the use of a garden hose on limited days of the week or during certain restricted hours of the day.

Because of this unlimited use, the peak rates of consumption during the afternoon and evening hours on hot summer days approached 3.6 mgd. Thus, these peak rates were equivalent to the design rates. An examination of the curve showing water consumption indicates that the daily average usage in 1957 will be approximately 900,000 gal (see Fig. 3). The peak rates were thus four times the average daily rate of consumption.

When the system as now in operation was laid out, it was recognized that in order to meet peak rates at future dates, it would be necessary to provide an elevated water-storage tank at some point in the District that would float on the system and would discharge water for consumption during the critical hours of daily usage. The Commissioners recognize the fact that the day has now come when serious consideration must be given to the erection of an elevated water-storage tank. The growth of the District and the maintaining of a proper rate for sale of of water will result in funds being available to meet the necessary bond payments for such an expansion program.

An examination of the curve on income (Fig. 5) shows that there was a decrease in 1954. Prior to that year, the income steadily increased, as a result of either growth of the District, or an upward adjustment of water rates, or because of both. The water consumers had been promised by the Commissioners that if the program as proposed worked out satisfactorily, and if income exceeded the actual necessary funds for operating the District, a reduction in the rate of water would be put into effect as soon as practicable. It was felt that in 1954 the minimum rate of $10 per quarter per family could be reduced to $9 per quarter per family. Such a reduction was voted and, consequently, the income for 1954 was less than that for 1953. The continued growth of the District naturally resulted in an upswing of the income curve, and by 1958 it is estimated that the income from the sale of water will be $120,000 annually.

Water rates in many local communities have been climbing. Rather than being out of step, so to speak, the rates of Fire District No. 1 are now becoming more in line with surrounding

communities, as they have in turn raised their rates. Fire District No. 1 has been ahead of many other communities, in that they have had the income to finance improvements to keep ahead of the demand for water by the ever-increasing population.

Except for a very minor interest payment each year, all costs for operating the Water Department are taken from water revenue and related receipts. Tax payments paid to the Fire District by property owners in the District are used entirely for the operation of the Fire Department.

THE MF MILLIPORE FILTER—ITS USES AND APPLICATIONS

BY DONALD W. MacLEAN*

[*Read at Chemists' Session, Dec. 19, 1957.*]

The Millipore Filter evolved as the result of a military need. When laboratory facilities and material supplies were destroyed by Allied bombing in World War II, German scientists turned to "membrane" filters as a means of determining the bacterial content of public and military water supplies. These unique cellulosic filter discs—although at the time somewhat crude and unstable—were able to retain, on their surface, all of the bacteria from a sample of water passed through them in a suitably-designed filter apparatus. The invisible bacteria were subsequently cultured into visible colonies directly on the filter disc, so that identification and enumeration were possible. Perhaps the most significant characteristic of this "emergency" technique proved to be the speed with which the test could be done. The membrane filter actually *reduced* the time required for an accurate bacteriological analysis from 4 days to 6-20 hours.

Membrane filters, attributed originally to Fick in 1855, had been under development for bacteriological use by both Russia and Germany for several decades prior to the war. On the basis of the Germans' wartime success with the filter, the U. S. Army Chemical Corps instigated a thorough research program at the California Institute of Technology, to establish improved methods for making and using membrane filters. The Lovell Chemical Co. of Watertown, Mass., continued this effort by developing practical methods of mass-producing various types of membranes. From this operation the Millipore Filter Corp. was formed in June, 1953, to manufacture—on a large scale—the "MF" Millipore Filter and related items of apparatus. Specific MF manufacturing processes are still subject to strict governmental security regulations, largely because of MF's vastly superior

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quality and technical versatility as compared to those of foreign make.

The MF Millipore Filter is a thin cellulosic sheet material, approximately 0.006 in. (150 microns) in thickness. It is made in 10 precisely controlled porosity grades (ranging from 5 microns down to 10 millicrons), each having extremely small, yet perfectly uniform, capillary pores which pass from top surface to bottom through its structure. The type HA Millipore Filter, for example, has approximately *50 million* of these pores—each one 0.45 microns ± 0.02 microns in diameter—in *each square centimeter* of its surface area. It thus resembles in some respects a honeycomb of microscopic dimension.

The MF functions like a screen or sieve, providing an absolute *surface* retention from liquids or gases of *all* solid particles which are larger than the specified MF pore size. Despite the minute size of the pores, flow rates through the Millipore are incredibly high because of the high ratio of pores (80%) to solid matrix (20%). The MF contains more *space* and less *substance* than perhaps any other material man has ever made.

Any solid particles—whether bacterial organisms, viruses, dust or metallic particles, pollens, smokes and fumes, or whatever—may be quickly and easily removed from a liquid or gaseous sample and transferred to the surface of the filter by simply passing the sample through the MF disc. In the case of bacteria, each invisible organism thus deposited on the filter surface may then be cultured directly on the MF into a visible and identifiable bacterial colony. By simply observing the number and type of colonies which develop, the scientist can determine the *exact* original bacterial content of his liquid or gaseous sample volume. In the case of dust and other inorganic particles, the MF may be rendered absolutely transparent by applying an immersion oil to its surface, for examining the particles under a microscope. Because of its low and uniform tare weight, the MF is also extremely useful for gravimetric determinations of solid particles.

The most significant general characteristics of this rather remarkable analytical tool, therefore, are its ability to retain *quantitatively* all particles above a specific microscopic size from *large* sample volumes of liquids and gases and its ability to hold

these particles in a single *plane* on the filter *surface,* where they may be readily examined or tested. Let us now consider, in greater detail, the MF's application for the bacteriological examination of water.

The bacteriological analysis of a water supply is the most valuable examination carried out in determining the suitability of the supply for drinking purposes. The detection of coliform bacteria in water is regarded as direct evidence of fecal contamination and, therefore, of the possible presence of pathogenic enteric organisms responsible for such diseases as typhoid fever, dysentery and cholera.

The presence of a few coliform organisms in a water sample does not, in itself, render the water unfit for consumption, particularly since many coliform types are native to soils. However, both coliforms and water-borne *pathogens* exist under like conditions, although millions of coliforms usually occur for every typhoid bacillus. The relative abundance of coliforms in the water, therefore, is highly significant from the standpoint of the possibility of infection by disease-causing bacteria.

Presently known methods for the isolation and identification of specific pathogenic organisms are much too complex and time-consuming for routine use. The coliform bacterial group, on the other hand, is easily isolated and identified. Accordingly, standards for drinking-water quality have been based on the relative number of coliform organisms in a water sample, and maximum allowable concentrations of coliforms have been established to assure proper and safe sanitary control.

The MF Millipore Filter makes possible a much more rapid and more accurate determination of coliform densities in larger-volume water samples than any other procedure in routine use. In many instances, the MF will detect the presence of bacteria where conventional methods fail. Of extreme importance, the MF provides a *direct* determination of the bacterial density, as opposed to a statistical estimate, and does so in one-fourth the time required for the conventional fermentation-tube technique.

By filtering a sample of water through an MF disc, in a suitable filter apparatus, all bacteria present in the sample will be retained directly on the *surface* of the MF. Each organism thus retained on the MF may then be developed into a visible

bacterial colony by superimposing the filter disc on an absorbent paper pad, saturated with a liquid nutrient medium, and incubating at approximately body temperature for 16 to 20 hours. In the presence of a differential type nutrient medium, such as MF Endo broth, the colonies resulting from the growth of coliform bacteria will exhibit a unique characteristic, such as a golden, metallic sheen. Furthermore, a differential medium will suppress the growth of the non-coliform organisms and will effectively prevent the development of a sheen or other such distinguishing characteristic on non-coliform colonies. Thus, differentiation between coliform and non-coliform colonies is possible.

Since each colony evident on the MF following incubation indicates the original presence of a single organism, a quantitative count of the coliform colonies on the MF will reveal the total number of coliform bacteria originally contained in the water sample. The results of the analysis are usually reported in terms of the number of coliform organisms in 100 ml of sample.

The United States Public Health Service establishes the only available national standard for water quality in the United States in the so-called *Drinking Water Standards*. On March 1, 1957, the U.S.P.H.S. amended these regulations to permit the official use of the membrane-filter procedure in the examination of water. It furthermore established the standard or quality limit of *1 coliform organism per 100 ml* as the maximum allowable arithmetic-mean density of all standard samples examined per month by the MF method. The National Research Council of the National Academy of Sciences has also recommended the MF method for use by the Armed Forces for the sanitary control of water supplies.† Before outlining the actual filtration technique, let us review the preparatory steps and some general considerations for the MF procedure.

The type HA MF has a pore-size specification of 0.45 micron and is routinely used for water-analysis work. It is

†Editor's Note: On Nov. 7, 1957, the Executive Committee of AWWA approved the unanimous recommendation of the Officers of the Water Purification Division that members of AWWA in responsible charge of laboratories having to do with the production of water for public use consider themselves at liberty to use the membrane filter procedure, provided that the laboratory administrator has satisfied himself by comparison tests that the membrane filter procedure produces results which are essentially equal to the completed test, and that the state sanitary engineering laboratory approves the application of the membrane filter procedure to public water supplies under its jurisdiction. (Jour. Am. Water Works Assoc., Vol. 50, No. 1, p. 73, Jan., 1958.)

available either plain or grid marked. Each square of the grid marking represents 1/100th of the total effective filtering area of the MF disc when used in a standard Millipore hydrosol filter apparatus. Type HA filters are normally packaged in resealable Kraft envelopes, immediately ready for autoclave sterilization at 15 psi for 15 minutes. Each envelope contains 10 filters and 10 absorbent pads.

The other materials and supplies for water analysis with the MF are few in number. In addition to a filter holder, we require a pair of stamp-type *forceps* for handling the Millipore Filter, a bottle of broth-type nutrient *medium*, a graduated 10-ml *pipette* for dispensing the medium, a supply of *absorbent pads* (always supplied with the filters), and a supply of covered *culturing dishes*, such as the MF disposable plastic petri dishes.

The standard MF Filter Holder consists of a base part, which supports the filter disc, and a funnel which clamps to the base and holds the filter disc in position (See Fig. 1). The entire holder assembly is held in the neck of a standard vacuum filter flask by means of a rubber stopper. The MF Filter Holder *need not* be re-sterilized between successive sample filtrations. Several years of routine use have shown that a thorough rinsing of the funnel walls with sterile water between samples is sufficient for normal water-analysis work. As startling as it seems, samples of finished waters in Wyandotte, Mich., have been routinely examined for many months *immediately following* samples of *raw* river water with only a sterile water rinse between samples. In only one instance—and that after a period of 6 months—did one single coliform colony develop on the finished-water MF. In spite of this experience, it is recommended that the filter holder be sterilized in an autoclave prior to the *start* of each day's testing.

A wide variety of dehydrated nutrient media for use with the MF is now commercially available. Of particular concern to us, however, are those media for the cultivation of coliform organisms.

Many of you are familiar with the MF technique as described in the current Tenth Edition of *Standard Methods for the Examination of Water, Sewage and Industrial Wastes*. This procedure specifies the use of two different media: a general

FIG. 1.—MILLIPORE HYDROSOL STANDARD FILTER HOLDER WITH FIELD STERILIZATION BASE AND COVER (SHOWN WITH A BOX OF 47-MM TYPE HA MILLIPORE FILTERS AND A BOX OF PLASTIC DISPOSABLE PETRI DISHES).

enrichment broth for a preliminary 2-hour stage of incubation, and a differential-type medium for a final 20-hour incubation period. The Millipore Filter Corp. has recently developed a much-improved "one-step" coliform medium called MF Endo, which eliminates the need for a preliminary enrichment period and provides an improved degree of differentiation between coliform and non-coliform colonies. In a comprehensive evaluation study of this new MF-Endo medium,* Fifield and Schaufus report the production of excellent clear-cut sheen characteristics on coliform colonies. Of 1,231 sheen colonies picked from 255 filters, 92.3% were confirmed as coliforms. Of 1,222 non-sheen colonies picked from 255 filters, 93.6% confirmed as non-coliforms. A modification of the basic Endo formulation, this medium utilizes a fuchsin-sulfite indicator, which is complexed by aldehydes produced by the fermentation of lactose by coliform organisms, thus giving a characteristic greenish-golden color to the coliform colonies (See Fig. 2). MF Endo Medium is available from all major media suppliers in dehydrated form and may be easily and quickly rehydrated. Approximate 2.0-ml portions of prepared MF Endo Medium are dispensed into sterile petri dishes with a sterile pipette. A sterile absorbent pad is then placed in each dish with flamed forceps. The absorbent pad evenly distributes the medium across the bottom of the dish and serves as a sort of "reservoir", to supply medium to the MF which will be placed on its surface. With a supply of prepared petri dishes ready, let us now proceed with the actual filtration and cultivation procedure. A sterile disc is removed from between its protective papers with sterile forceps directly from the Kraft Autoclave Pack envelope and placed on the base portion of the MF Filter Holder.

Next, the funnel is placed in position and clamped to the base. Then a measured sample of the water to be tested is poured into the funnel. Ordinary sterility practices, such as flaming the tip of the sample bottle, should, of course, be observed. In testing potable waters, the sample size generally will run from 50 to 200 ml, depending on the bacterial and physical characteristics of the water. In highly turbid waters, where clogging of

*Fifield, Charles W., and Schaufus, Charles P. "MF-Endo—an Improved Membrane Filter Medium for the Detection of Coliform Organisms in Water", J. Amer. Water Works Assoc., In Press (1957).

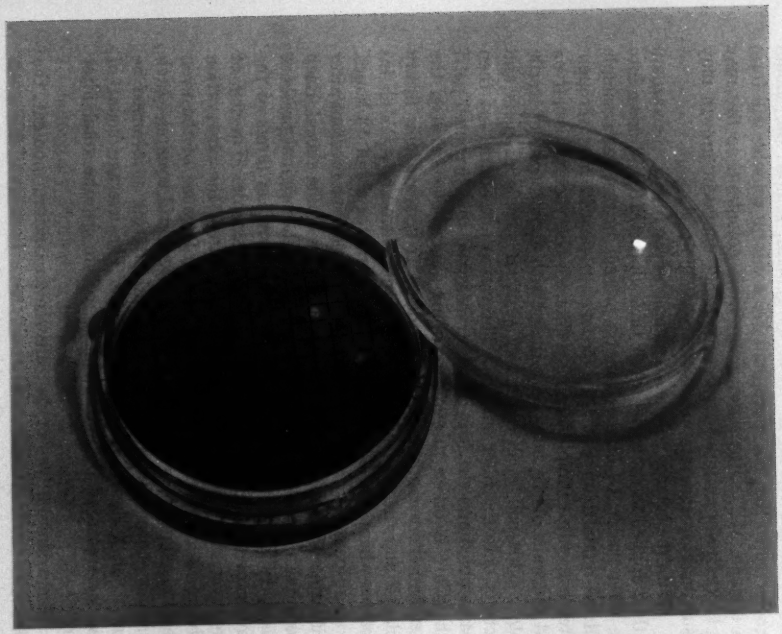

FIG. 2.—THESE TYPICAL COLIFORM "SHEEN" COLONIES ON THE SURFACE OF THE MILLIPORE FILTER ARE INDICATIVE OF WATER CONTAMINATION. (MF-ENDO MEDIUM IS USED WITH 18 HOURS INCUBATION AT 35°C. IN A PLASTIC DISPOSABLE PETRI DISH.)

the filter could occur, a minimal sample may be divided between two or more filter discs. For raw waters, an appropriately smaller sample should be used. In general, sample size should be selected so that not more than 300 coliform colonies will form on a single MF. Oftentimes, many more colonies than this may be successfully cultured on the filter, but confluent growth may result making accurate counts more difficult.

With the correct volume of sample in the funnel, the vacuum is then applied to draw the water through the MF and down into the filter flask. *All* of the bacteria present in the water sample will be retained on the filter surface—*none* will pass through. After the entire sample has been filtered, the vacuum is left *on* and the walls of the funnel are rinsed with about 20 ml of sterile water. This will wash down any residual sample droplets and bacteria onto the filter surface. The clamp and funnel are then disassembled and the MF disc is transferred to a prepared petri dish. Care is taken to avoid trapping air bubbles between the filter and the pad. The covers of the petri dish are now firmly replaced and the dishes are inverted and placed in a 35°C. incubator, where they will remain undisturbed for about 18 hours.

Coliform colonies developed by the Endo-type medium after incubation will show a characteristic golden metallic sheen. Each colony with these characteristics represents the original presence of one coliform organism. Results are reported in terms of the number of coliform bacteria in 100 ml of sample. The use of low-power magnification (10 X) will facilitate the observation of bacterial colonies on the filter surface. Because of the even colony distribution which results, only a few grid squares—each equalling one one-hundredth of the total filtering area—need be counted on a densely populated filter. The average count of these squares may be multiplied by 100 to get the total filter count.

For a simple "yes or no" answer on coliform content, the confirmed results of this test would have been available even earlier than in 18 hours. Consider the value of this in checking newly installed or repaired water mains, where service must be resumed in the shortest possible time. Consider, also, its value in controlling water-treatment dosage, or in obtaining the most rapid results possible in time of disaster. Here, truly, is the

means for an *accurate, direct, quantitative* analysis of the coliform bacterial content in the water sample—not an approximation based on statistical probability. Here, too, is the means for a positive *qualitative* analysis as well, for only the coliform colonies exhibit the characteristic sheen.

We have now reviewed the complete laboratory procedure for water analysis with the MF. Only 7 simple steps are involved:

1. The MF filters and apparatus were autoclaved.
2. The MF Endo medium was prepared.
3. The medium and absorbent pads were placed in petri dishes.
4. The water sample was filtered through a type HA Millipore Filter.
5. The funnel walls were rinsed with sterile water.
6. The MF was then placed in a prepared petri dish and incubated for 16-18 hours.
7. The resulting coliform-sheen colonies were counted and related to the volume of water sample.

The same level of precision, speed and convenience is also possible in the *field* with the Millipore Field Monitoring Kit (See Fig. 3). The standard kit contains all the materials necessary for two complete bacterial tests, including two sterile, disposable, plastic Monitor units, which serve as combination filter holders and culturing dishes; two sterile ampules of liquid nutrient medium, and two sterile, plastic sampling tubes. The kit is packaged in a small, convenient mailing box, to allow easy and thrifty shipment to a central laboratory, if desired. Designed particularly for use in areas where laboratory facilities are unavailable or inconvenient, the new technique requires only a supply of the small Field Monitors, a syringe and valve for pulling the water sample through the filter (see Fig. 4), a stainless steel measuring cup, and a portable incubator for culturing (if laboratory incubation is not feasible).

Utilizing the same basic Millipore Filter testing procedures, the Field Monitoring Kit also yields accurate, direct determinations of the bacterial content of waters in as short a time as 16 to 18 hours. A sample of the proper size is taken in the stainless steel cup, after the cup is thoroughly rinsed in the same water from which the sample is to be taken. The protective rubber caps are removed from the Monitor, and the syringe

FIG. 3.—MILLIPORE FIELD MONITORING KIT FOR THE BACTERIAL ANALYSIS OF WATER SUPPLIES IN THE FIELD. (ALL MATERIAL FOR TWO TESTS IS INCLUDED IN EACH KIT IN PRE-STERILIZED DISPOSABLE FORM, REQUIRING ONLY A SYRINGE TO DRAW THE SAMPLE THROUGH THE MONITOR UNIT.)

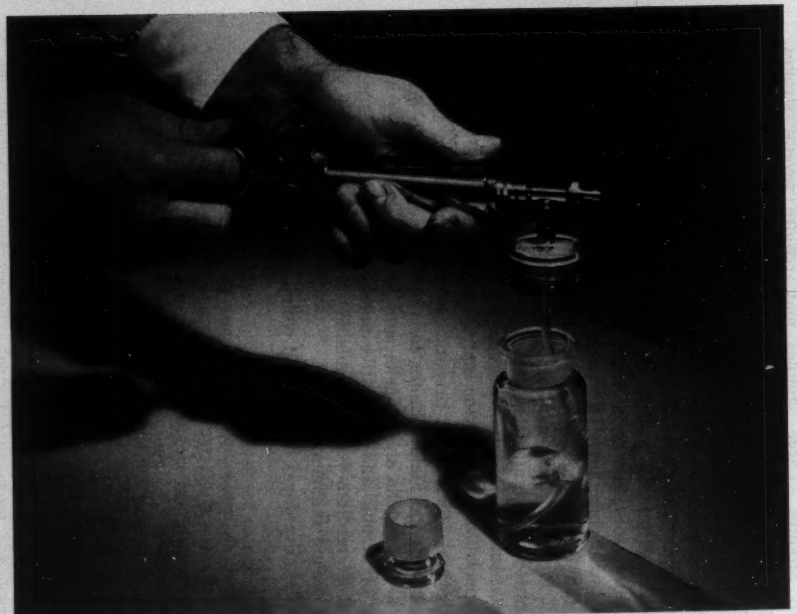

FIG. 4.—MILLIPORE FIELD MONITOR ASSEMBLED TO AN ALL-METAL SYRINGE AND TWO-WAY VALVE. (WATER SAMPLE IS DRAWN UP THROUGH THE STERILE SAMPLING TUBE AND MONITOR UNIT WITH A FEW STROKES OF THE SYRINGE.)

valve and sterile sampling tube are plugged in. The syringe plunger is then drawn back to pull the sample up through the Field Monitor. Large samples may require several strokes. The plastic sampling tube is then removed and discarded. The scored tip of the ampule of MF-Endo medium is then broken and the ampule inserted into the Monitor. The scored top of the ampule is then broken off and the ampule lifted very slightly, to allow the medium to flow into the Monitor. One stroke of the syringe will draw the medium through the filter, so that the underlying absorbent pad is left saturated with medium. The protective caps are then replaced, and the Field Monitors are incubated for about 18 hours at 35°C. in the portable incubator or replaced in their boxes and forwarded to a central laboratory for incubation. In an emergency, Monitors may be incubated in the field by placing them in a special vest next to the body.

Several other media preparations are available in ampules for use with the Field Monitor for the detection of such organisms as Salmonella and Shigella, and for total counts of a wide range of aerobic and facultative anaerobic bacteria. A special "holding" medium is also available to preserve organism viability during shipment.

The advantages of this field technique may be summarized as follows:

1. Relatively large samples of water may be tested, and thus the positive detection of even slight contamination may be assured.
2. The costly and inconvenient shipment of glass water bottles is eliminated. This also prevents changes in the bacterial population density during shipment.
3. A *direct* count of the organisms results, rather than an approximation—and in a much shorter time than by present techniques.
4. No laboratory facilities are required. Dishwashing and sterilization of glassware and media is eliminated. No preparation, no clean-up.
5. Immediate incubation is possible at the sampling site in the portable field incubator.
6. One central incubation facility may be used, if desirable, to serve a very large area. Kits may be mailed from the sampling site to the laboratory at very little expense.

7. The Field Monitoring Kit is simple to use, requiring no special skills, thus saving valuable professional time for more critical laboratory operations.
8. As in the standard MF laboratory procedure, the filter may be dried and retained as a permanent record of the test results.

The Field Monitoring Kit has been recommended by the U.S. Navy for use by its Preventive Medicine Units and has already found extensive use in World Health Organization laboratories throughout the world. Many municipal and state water-testing departments in the United States have reported that the Field Monitor is particularly useful in checking newly installed pipelines, wells, swimming pools, etc., where accuracy and rapid determination of results is important.

The MF may very advantageously be employed for a *biological* examination of water, sewage sludge, or bottom materials as well. A sample of appropriate size is drawn through a 1″-diameter type HA filter in an MF Pyrex Microanalysis Filter Holder to concentrate all of the organisms, such as microplankton and algae, in the sample. After drying the MF on an absorbent pad for 10 minutes, it is placed directly on a few drops of high-viscosity microscope immersion oil on a clean glass microscope slide. This action will render the MF completely transparent. An immersion oil whose index of refraction approximates that of the filter must be used—about 1.50. The slide is then placed on the stage of a microscope for examination by transmitted light. The organisms may then be counted with the aid of a Whipple micrometer disc in the ocular, as described in the Tenth Edition of *Standard Methods*. Focal readjustment from field to field is unnecessary, since the organisms lie in a plane on the filter surface. The breakup of material—often encountered as a result of agitation—is all but eliminated with the MF. More accurate identification is therefore possible. Of greater significance, however, is the fact that the organisms are held immobile on the filter during examination. An accurate quantitative analysis results, furthermore, since the organisms are entirely concentrated from a known volume of sample. Here, again, the MF and slide may be kept as a permanent record of the analysis.

We have now covered the complete description of the use

of the MF Millipore Filter for water analyses—both bacteriological and biological. We have seen how it is used in the laboratory and in the field.

A great many other MF techniques are now in widespread use. All of thees techniques represent highly significant advantages in terms of accuracy, speed, ease and economy over the methods in general use before the MF was developed. The following examples are typical:

Biological Warfare (BW). The MF provides the most rapid means of detecting the deliberate bacteriological contamination of air, food and water supplies in the event of an enemy BW attack.

Industrial Bacteriology. As a means of analytical control in the brewing, food, soft drink, sugar, pharmaceutical, milk and dairy industries, etc., the MF provides more rapid and accurate identification of harmful bacteria, yeasts and molds accidentally present in the foods and drugs.

Industrial Air Sampling. The MF is the most efficient collection medium now known for the routine study of air-borne health hazards, such as dusts, pollens, metallic fumes, acid mists, etc. The city of New York, for example, in the Laboratory of the Department of Air Pollution Control, routinely uses the MF and has done so for more than a year.

Radioactivity Studies. The MF is widely used in the nuclear field, because its surface-retention characteristic prevents the absorption of alpha energy by the filter itself. Ordinary filter papers, which trap particles deep within their matrix, shield much of the radiation from accurate detection. Measurements of radioactive particles in liquids and gases with the MF, therefore, are vastly more accurate. In many atomic installations, such as the Knolls Atomic Power Laboratory, the MF has been adopted as the 100% efficiency standard for radioactivity sampling.

Sterilization by Filtration. Since many new drugs and pharmaceuticals cannot be safely sterilized by heat or other conventional means, the MF is being used to render these materials bacteria-free. It is also widely used as a sterilizing medium for make-up waters and for process air throughout the drug industry.

Microscopy. The ability of the MF to be rendered completely transparent by applying a drop or two of microscope immersion oil ($N_r = 1.5$) is of extreme importance in the examination of dust and contamination particles with the optical microscope by transmitted light. Of even greater usefulness, however, is the technique of dissolving the MF from beneath ultra-tiny particles (virus, for example) directly on a formvar grid for examination with the electron-microscope.

Meteorology. Among other meteorological techniques, the MF is currently being used in the Antarctic during the Geophysical Year, to analyze material in melted ice samples taken at various depths in the ice cap. By identifying the geographical source of the microscopic dust and mineral particles thus found at specific levels, scientists are able to determine prevailing wind directions of *thousands* of years ago. Long-range climatic forecasts are now being aided by just such information.

Secondary Oil-Well Injection Water. When internal well pressures are no longer sufficient to squeeze residual oil out of the underground oil-bearing rock formations, water is injected into the well to force it out. To avoid clogging the finely porous rock structure with minute particles or organisms in the water, the MF is constantly used for the analysis of the field water supply before and during injection.

Medicine—Surgery. Virtually every disease-causing bacterium may be cultivated on the MF for diagnostic purposes, and many grow much more rapidly than on standard nutrient plates. Tuberculosis, for example, may now be accurately diagnosed in *3 days* with the MF, as opposed to about 28 days with conventional methods. Among other surgical techniques, the MF is being used during cancer surgery as a rapid means of checking for the presence of "spilled" malignant cells before the incision is closed.

Guided Missiles—Jet Aircraft. Despite extreme care in the design, construction, handling and cleaning of hydraulically operated servomechanism control systems for missiles and aircraft, micron-sized particles and fibers—present in every hydraulic fluid and system—often become lodged in valves of extremely close tolerance, causing equipment failure. While military security prevents specific details, this problem of unreliability has been a well-publicized headache to missile and aircraft people, to the military, and to their suppliers. The MF, however, has now provided the engineers of virtually every major missile activity with the only effective means of determining the *exact* nature and the *total* extent of contamination in their hydraulic fluids. These analytical techniques have been formalized by the Society of Automotive Engineers in October, 1957, as an industry-wide standard method to be used in this field.

There are *many* other applications—some routine and simple, some exciting and complex. Of interest to many chemists as well is the test for suspended solids in sewage with the MF. The procedure is similar in many respects to the biological examination, but is based upon a gravimetric determination instead of a microscopic count. A pre-weighed, dry, type RA Millipore Filter is employed, through which a sample of sewage is passed.

The filter is then rinsed with distilled water while still in the Filter Holder. After disassembly, the filter disc is desiccated and reweighed, to determine the total weight of suspended solids in the sample. This same filter may then be ashed at 600°F. for 10-15 minutes and the residual weighed, to determine the weight of volatile suspended solids. The Millipore Filter will ash to 0.0000 gm at 600°F.

New and valuable applications of this remarkable analytical tool are constantly coming to light. You will hear a great deal more of the MF in time to come.

NEW GROUND-WATER SUPPLY FOR AUGUSTA WATER DISTRICT

BY SIDNEY S. ANTHONY*

[*Read December 19, 1957.*]

The basis of the present system of water supply in Augusta was installed in 1886, consisting of about 21 miles of pipe, mostly cast-iron, a 6-mil gal earth-embankment reservoir on the hill west of town, 419 service connections and 86 hydrants, with supply taken from the Kennebec River above the dam operated by the cotton mill. During the next 15 to 18 years about ten miles of mains were installed; 1,100 new services, 40 hydrants and a filter were added, but the supply still came from the river.

In the early years of the 20th century, added population and industries up river caused a pollution problem, which was not remedied by the simple filter that was used, and several epidemics of water-borne disease broke out in Augusta, the worst occurring during the winter of 1903, when there were more than 300 cases of typhoid fever and about 30 deaths.

A new supply was indicated, but beyond the resources of the privately owned water company. It was about this time that the Water District idea was brought forth by our old friend, Harvey Doane Eaton of Waterville. A charter was sought in the Legislature and granted by it, and the works were taken over by the District in May of 1904. I believe the Augusta Water District was the second charter of this nature granted by the State, the Kennebec Water District's charter being granted earlier. The Augusta Water District was, however, the first to be organized and in business as such.

Rights were granted the new District to take water from Cobbosseecontee Lake, China Lake, Carleton Pond and the Kennebec River. Much preliminary engineering took place, with careful studies made of all possible sources of water in the vicinity. Carleton Pond in Readfield was finally selected as the source,

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since it was located about 300 ft above the city, about nine miles away, and was of excellent quality.

Land and water rights were purchased, including a fish hatchery belonging to the State; the dam was raised to elev. 333.0, and a pipeline was constructed to the existing reservoir in Augusta.

The water from Carleton Pond flowed by gravity to the village of East Winthrop on the shore of Lake Cobbosseecontee through a 20-in. pipe. At this point a brick pumping station was built, containing two electric pumps, one of 2-mgd capacity and the other 3-mgd.

From the pumping station to the reservoir a 24-in. cast-iron pipe was laid with only incidental service connections attached, since it wandered through the countryside in a line which would keep it below the hydraulic gradient. It did not follow any highway except for a few hundred feet in the village of East Winthrop. The pumping head was very low, being wholly friction losses in the supply main, since the pond was 8 ft higher than the reservoir.

The pumping station also contained a Deane steam pump, with a capacity of 3 mgd under much greater operating head. An intake from Lake Cobbosseecontee at elev. 171 was connected to the steam pump, which had to raise the water 153 ft to the reservoir through this same 24-in. pipeline. Coal to supply the boiler, which in turn operated the steam pump, was carried in electric cars over the then new Augusta & Winthrop line, with a spur track to the station yard and the coal pile. This spur track accounts for the peculiar curve to the drive which is used at present, since the drive followed the spur track. We still have 35 to 40 tons of soft coal out there which has been used in grading the grounds.

The steam pump was started on January 18, 1906, and the Kennebec River allowed to slumber peacefully thereafter. This was only eight months after work was started on the new supply, which is quite a feat when it is remembered that all was hand work.

The new supply was adequate until recent years. In the beginning the system used about 2 mgd, much of it without the

need for pumping except in late summer, when the pond was low.

The steam pump from Cobbosseecontee was used for a few months, while the Carleton Pond line was being completed, and again in 1912, when a break in the line between the pumping station and the pond made this step necessary. After that the steam pump was never again used and was dismantled in 1931, being replaced by an electric pump with the same capacity. This also has been used infrequently, since Carleton Pond continued to supply all water needed, except during extremely dry periods.

In 1928 the old 2-mgd pump was replaced by a 4-mgd pump, and in 1950 the old 3-mgd pump was replaced by a 5-mgd pump, to take care of the occasional peak-demand days, which once in a while reach that figure. Four-mgd days are fairly frequent during hot dry summers.

Water consumption remained steady at about 2 mgd until 1941, when a steady increase in demand developed to the point where in 1952, 1954, 1955 and 1956 we used an average for the year of more than 3 mgd—a sad strain on the small watershed of Carleton Pond, which is only 2.6 sq mi.

In the early 1950's we began to consider additional sources of water. Of course Lake Cobbosseecontee was always available, but the increasing age of the pipe raised the friction losses to the point where pumping through the 24-in. main at a rate greater than 4 mgd was impracticable. The further fact that we were still dependent on a single line of pipe about 9 miles long was a weakness which should be eliminated.

We studied a system of small ponds northeast of the city and found the water quality undesirable and the cost of developing to be about $1,000,000.

A second supply line from the East Winthrop Pumping Station, routed along the main highway, was found to be possible with a short detour around a high hill at the western edge of Augusta. A line of this type would have required extensive alterations to the pumping station and its equipment, which added up to about $1,000,000 also.

Raising of the dam at Carleton Pond to conserve the infrequent spring overfall was studied. Excess precipitation would

have been so infrequent that it is doubtful if the added storage would have been filled more frequently than once in ten years. This was obviously not the answer.

An underground supply seemed to be the only solution to our problem, and in 1951 we engaged Metcalf & Eddy to study this feature. The Rev. Daniel Linehan, S.J., of Weston College came to Augusta in the summer of 1951 with his "electronic dousing rods" and toured our area extensively, locating two areas which were worth exploration and proving that several sites which we thought were good were practically useless as aquifers.

We sank an 8-in. test well in one location and found 120 ft of beautiful gravel, but it contained enough clay so that its yield was almost microscopic. The other location proved better, and an 8-in. well yielded more than 40 gpm per foot of drawdown after a sustained pumping of three days. Another location about 1,000 ft away also looked good on his graphs, but we did not test it at that time, and the project was postponed.

After the wettest year (1954) in recent memory, we decided to proceed with the development of the new well supply in the Bond Brook area, which we had studied carefully in 1951. It is well we started when we did, as 1955 was dry, 1956 just a little below normal, and 1957 about as dry as they come.

Early in the spring of 1955 we engaged R. E. Chapman Co. of Oakdale, Mass., to do some exploration by means of 2-in wells in various localities that had not been investigated by Metcalf & Eddy and Father Linehan. Since none proved as good as we had hoped, we returned to the Bond Brook area and ran a large number of test wells to bed rock in the whole area.

The two locations suggested by Father Linehan looked the best, and we proceeded with a contract for two wells, driving a 24-in. casing to bed rock and placing an 18-in. casing with 20 ft of Johnson screen at the bottom of each. The space between the 18-in. and the 24-in. pipes was then packed with graded gravel and each well surged for a considerable length of time. After all fines had been removed, diesel-driven turbine pumps were placed in each well and discharged to the nearby brook, with calibrated nozzles placed on the discharge end of each.

The log of the two wells showed the following results:

Brookside Well		*Triangle Well*	
0-15 ft	clay	0-15 ft	grey clay
15-20	gray gravel	15-40	grey sand
20-30	fine sand	40-45	grey sand and clay W.B.
30-55	coarse sand W.B.	45-50	medium grey sand W.B.
55-60	fine sand W.B.	50-89	coarse grey gravel W.B.
60-65	coarse sand W.B.	89	ledge
65-85	coarse gravel W.B.		
87	ledge		

Brookside Well	*Triangle Well*
Static 7'6" from top of 18" casing	Static from top of casing 12'0"
18" casing above ground 6"	Casing is 1'5" above ground
Screen placed 5 ft 80-slot	Screen placed 20 ft of 140-slot
5 ft 150-slot	
10 ft 200-slot	

The wells were designated as follows: "Brookside" for the one nearest Bond Brook, and "Triangle" from the fact that it was located in the middle of a triangular meadow, bounded by Bond Brook, Bond Brook Road and the Leighton Road.

As the prospects for adequate water were good, we negotiated with land owners to purchase the property and were fortunate in being able to buy the whole triangular meadow, with a 200-ft strip across the road from it, containing in all about 5 acres, and the Brookside location, containing 12 acres of wooded land and a gravel bank. As a further protection we purchased the narrow strip of land opposite the Brookside Well between Bond Brook Road and Bond Brook, containing about ½ acre.

The tests of the wells proved their capacity to be greater than expected. We get about 25 ft of drawdown at 1,000 gpm in each well. Each has dropped only five or six feet since March first, even though each has at times been pumped continuously for 24 to 60 hours.

Two 8-in. Fairbanks-Morse pumps were supplied by R. H. White Construction Co. of Auburn, Mass., and installed by them. Electrical equipment was purchased locally through Westinghouse Corp., and metering and control equipment was furnished by B-I-F Industries of Islington, Mass.

We seldom operate the two wells together, since discharge heads are somewhat higher, with consequent higher pumping costs per mg. Normal pumping is 1,000 gpm for each when operated separately. When operating simultaneously we lose about 80 gpm from each, and therefore we alternate operating cycles.

We started at once (summer, 1955) to install a transmission main from the well locations to the city.

The most convenient point at which to introduce the well water to the existing system was on Mount Vernon Ave., at a point where a 16-in. main crossed between the reservoir and the business and industrial section, near the cotton mill. This was a pipe installed in 1893 as a force main from the old Kennebec River pumps to the reservoir and could be tapped only 3,000 ft from the reservoir. This point was located about 12,000 ft from the wells. The new line proceeded from the wells about 7,000 ft along the shoulder of Bond Brook Road, joining Mount Vernon Ave. about a mile from the old main. Since this bituminous concrete road was then in process of being rebuilt as a part of the Secondary Highway System of Maine, we started at this point, installing sufficient pipe to permit finishing of the road, which was scheduled for completion that fall.

At the urban-suburban line, we left the roadway limits of the new highway and entered a strip between the sidewalk and the property line, which in no place was narrower than 7 ft, so that we were able to install this main with very little disturbance of the then very new paving. At one section we installed under the sidewalk, which had to be replaced later. When we left the new construction we were in a closely built-up section with pavement of asphalt macadam. For the next 2,600 ft we cut this paving 4 ft wide with paving breakers and installed our new main. From the urban-suburban line to the intown end of the project we were already serving customers by means of 6-in. and 8-in. pipe.

During all this portion of the installation we were fortunate in breaking only two or three service connections and a very few house sewers. At frequent intervals we cross-connected the old and the new mains, thus greatly improving both domestic and fire flows.

One of the most interesting parts of the project was the

crossing of Bond Brook, which we did three times in the 12,000 ft. The crossing nearest the city was on a bridge about 40 ft above the water surface, with steep banks on both sides. The bridge span being about 35 ft, we trenched up to each abutment, cut a hole in each, and pulled a steel truss made for the purpose from one hole to the other. We could not cut the bridge deck, as it was a reinforced-concrete slab resting on I-beam girders, permitting no disturbance. Our truss was fabricated with a slide-trough effect, and we inserted a length of pipe into it, jointed and insulated and pushed another after it, insulating as it disappeared from view. The assembly was pushed into the pipe on the other end of the bridge, and we continued to our destination.

The other two crossings were between the well locations, where the brook made a big ox-bow to the east. It was a case of going around the ox-bow and crossing one other inflowing small brook, or taking the short line across the loop, which we did, at a saving of four or five hundred feet of pipe. We seized the opportunity when the brook was at minimum flow in early August, and sent our back-hoe down one bank and up the other, in each crossing. Simple sandbag cofferdams kept the trench dry enough to work in on the first crossing, which was wide and shallow, so that one half of the channel could be dammed off and the brook diverted.

As the other was steeper, we borrowed from the city highway department a 20-ft length of 24-in. culvert pipe, laid it in the brook and then built a gravel road right across, on which our backhoe and men worked. Three-inch ditch pumps took care of all leakage with no trouble.

A week after this project the brook was 4 ft deep in fresh runoff after heavy showers.

The connection with the old force main was made by means of a 16x16 tap. The cut-out disc was anxiously awaited, to see what condition the 60-year-old pipe showed. The original tar coat was still showing, dulled somewhat by time, but still there. Also, in the 16-in. diameter disc we found two tubercles about 2 in. in diameter. We were gratified, to say the least.

The entire length of the project was installed with 16-in.

Class 200 Mechanical Joint pipe and fittings, all cement-lined. Costs of the pipe installation were as follows:

12,037 ft of 16-in. MJ pipe, all valves and fittings	$7.86 per foot
Labor	1.14 " "
Equipment (all owned by the District and charged to job on an hourly depreciation)	1.01 " "
Other charges, repaving streets, roads and sidewalks	.62 " "
Total cost per foot	$10.46
Total cost	$124,580.00

Pumping stations were designed as colonial brick structures and were identical, except for location of entrance door and windows. They were designed as one story and basement, with only the motor and control panels on the first floor, which was finished in knotty pine. The basement holds the meter, check and relief valves, and the top of the well shaft. Floors were finished in mottled green rubber tile. Heat is supplied mostly by the motors, and during shutdown time by electric heaters. Floors are designed of sufficient strength to support a Diesel auxiliary engine, if such later becomes desirable or necessary. Grounds have been landscaped, and shrubbery will be placed next spring.

The two pumping stations cost $9,980 on contract, with grading and landscaping done by our own men in odd moments during the past summer.

The entire costs of the project are divided as follows:

Land purchases	$7,000
Installation of wells	18,6662
Installation of force main	124,580
Pumping equipment	8,263
Electrical and control equipment	5,702
Pumping stations	10,426
Paving costs	7,529
	$182,162
Preliminary engineering and exploration	10,139
TOTAL COST	$192,301

Results of the installation have been gratifying. The Brookside Well was placed in operation on October 23, 1956, and the Triangle Well in March, 1957. Since January first they have provided 27.4% of the water required in the system, or 288.5 mil gal.

We have also drawn on our auxiliary supply, Lake Cobbosseecontee, for 209.3 mg or 19.8% of this year's use. If we had not had the wells and the auxiliary supply, we would have been dry, or at least not very damp, by the middle of last July, as we had only 250 mg in storage at the end of the spring runoff, rather than 700 mg as is normal. The spring runoff was practically nil, as all snowfall evaporated in the clear balmy skies of March and April of this year.

We consider this well-field area is capable of expansion, with more well installations possible upstream from the present locations as need develops in future years.

In closing, if and when you install new wells, watch out for the highway engineer. Six years ago, when we first investigated this area, it was far out in the country. As we began development we realized that the Maine Turnpike might eventually pass nearby and tried to get the exact location from their Chief, so that we could avoid being disturbed in future years. Since we were unsuccessful in this attempt, we placed our Brookside Well where we thought best. This summer, the engineers for the Interstate Highway passed by, and we found the center line of the 300-ft right-of-way only 104 feet from that well. We expect that we can avoid damage to the well by judicious grading and drainage of the highway.

No one had any idea that the Triangle Well might be in the way of anyone until this past week, when the Chief of the State Aid Division of the State Highway Department called and wanted to know if it mattered to us if the Leighton Road were relocated to the East of the Triangle Well, rather than to the West as it is now. It doesn't matter much, except that our new brick pumping station will be backed up to the road, rather than facing it with a nice bronze plaque and landscaping around the front door.

PRESSURE-TOOL CLEANING VERSUS CHAIN-HEAD CLEANING

BY RAYMOND F. BAHR, JR.*

[*Read December 19, 1957.*]

The purpose of this paper is to acquaint the water-works superintendent with the two methods of pipe cleaning described herein. The difference in the two methods of cleaning will be emphasized, and it will be seen that each method has distinct advantages over the other under dissimilar conditions.

Let us first discuss the pressure line-scraper method of cleaning, as it is probably the best known and most widely used method. Excavations are made at both ends of the line selected to be cleaned, and the pipe is cut at these locations. At the exit or downstream end of the line, the cut is long enough to permit the placement of a 22½° or 45° bend at the end of the pipe. Added to this bend is a length of pipe of the same diameter and long enough to reach out of the hole, so that water, tuberculation, and the tool will be discharged at street level. The joints are usually yarned and the bend is chained to the main, so that it won't blow off. The cut at the other end is normally made longer than the tool used, so that the tool can be winched or jacked into the nipple. If pumper connections are to be used, the tool is placed directly into the pipe. Some pressure tools, such as the one manufactured by Flexible, Inc., can be placed in the line, a section at a time. This greatly facilitates the loading when it is done directly into the pipe.

Placing the tool in the main is the most important phase of this method of cleaning. The depth of deposit, as well as its hardness and density should be taken into consideration, so that cleaning can be accomplished with one pass of the tool. This is important also, in order to eliminate the hazard of red water after cleaning. The tool should be fitted to the pipe, and new or more blades should be added, or spring tension should be increased in some manner. Most pressure tools will lose most of

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their spring tension after about 10 miles of cleaning. The gasket holes should be adjusted to the deposit, so that the proper amount of wash water will by-pass the tool and wash the scrapings ahead. Otherwise, the scrapings can bridge the line. The tool must fit in the line snugly; it should never go into the line without the aid of a jack or winch.

Another necessity for pressure-tool cleaning is adequate pressure. This is, of course, dependent on the pipe diameter, blade tension of tool, and hardness and density of deposit. The pressures given here are for a tool set to clean the line to 95% of its original carrying capacity in one pass with average deposit. A 6-in. tool will require 80 to 90 lb; an 8-in. will require 65 to 80 lb; a 10-in. will need 50 to 65 lb, and a 12-in., 35 to 50 lb. If poorly leaded joints are encountered, the pressure will have to be increased.

After the tool is loaded in the nipple or pipe, the nipple is replaced, if pumper connections are not used, by means of Dresser-type couplings. All hydrants and gates on the line are opened full, and all services are shut off. This is the most time-consuming phase of the work, if there are many services on the line. The gate behind the tool is then turned on slowly. All air must be removed from behind the tool, before the gate is opened sufficiently to start the cleaner. This can usually be determined by listening to the tool in the hole. The gate is then opened and the tool forced ahead at a slow walk. The gate may have to be opened more or turned down as the tool progresses, in accordance with its travel.

The tool should be followed as closely as possible, as it runs in the main. A stick, rod, or Geophones can be used. In case the cleaner is stopped by unmapped fittings, poorly leaded joints, or other obstructions, or by carrying sticks, it must be dug up.

Now let us look at another method of cleaning—that is, the chain-head method. This method is entirely different, in that work is done from one excavation; and the work is done against the flow of water. The work is started by excavating at the downstream end of the line and cutting out a piece, 2 to 3 ft long. The equipment used consists of three major items: a

power drive to push and turn the rods into the pipe, high-speed steel rods, and the cleaning head.

The cleaning head varies with the size of the pipe and the type of deposit that will be removed. The tool normally used for pipe diameters between 4 and 8 in. is called a chain head. This is a ¾-in.-round shaft about 10 in. long, with a nut on one end, so that it can be attached to the coupling on the rods. About five knockers, of 1¼-in. bar stock, 1 in. long, are attached to this by means of chain links. The chain links are of the proper size, so that when the knockers are spread out, they will correspond to slightly larger than the pipe diameter. All wearing surfaces should be hardfaced with stellite, nickel chromium, or by atomic hydrogen process, to eliminate wear.

This chain head is attached to 40 or 50 ft of rod and started into the pipe. The other end of the rods is hooked to the power drive. The rods are then rotated by the power drive, at a speed between 400 and 900 rpm, depending on the pipe size and deposit to be removed. The power drive also pushes the rods into the line at a constant forward speed, between 5 fpm and 20 fpm. This speed also would depend upon the deposit to be removed. After the first few feet have been cleaned, the operator can look up the line to see if the pipe is being cleaned properly. If not, the rotation or forward speed can be changed. Successive lengths of rod are added, as each section is pushed in the pipe.

Work is accomplished with a small amount of wash water coming back into the excavation. About ¼ pipe is sufficient. Too much water will hamper the cleaning action. The rods are also rotated as they are withdrawn from the pipe, so that most of the filings are removed. The line is then flushed. If flushing is done properly, there is no need to turn off services.

It has been proven by tests in mock pipes that there is no damage to corporations when this method of cleaning is done properly. Thousands of miles of actual rodding have further proven this fact.

The length of the run that can be made with this method of cleaning is shorter than with the pressure-tool method. Normally, 750 ft in one direction is the maximum distance that can be rodded. If there is flow in both directions, 750 ft can be rodded from one excavation in both directions, for a total of

1,500 ft. In certain circumstances work can be done with the flow to eliminate excavations further.

Therefore, we can see that each of these methods has advantages over the other.

For long runs (1,500 ft or more), especially transmission mains, the pressure-tool method is the only method to employ. There may be certain locations, however, on this type of run that would necessitate chain-head cleaning. If the line should go under a river or under buildings, it might be advantageous to chain-head this portion, as there is no chance of losing the chain head.

Some lines cannot be cleaned by the pressure-tool method because of the size. Pipe sizes under 6 in. would require excessive pressures. Four-inch pipe, for instance, would require about 200 lb of pressure. Also, the protrusion of the corporations in many cases is too great in relation to the pipe diameter, to allow the solid portion of the tool to pass. Also, the amount of tuberculation in a 4-in. pipe is usually very great in relation to the pipe area. This makes it very difficult to keep the scrapings from bridging the main.

Intake lines are another problem that is easily overcome by chain-head cleaning. The intake end can be sand-bagged or boarded, and the line can be cut downstream and rodded. Usually the leakage through the sandbags or boards is just the right amount of wash water.

The advantages of chain-head cleaning are very pronounced for short runs in residential or business sections. Corporations do not have to be shut off, and a definite commence-work and stop-work time can be adhered to. A definite shutdown time can, therefore, be given to the consumer—a very difficult thing to do with pressure-tool cleaning. Each run can usually be made from one excavation, a considerable sum thus being saved for the water department.

For any location where it would be very difficult and costly to retrieve a pressure tool, if it should get stuck, the chain-head method should be considered.

When any line is to be cleaned, consideration should be given to these methods, so that the work can be accomplished in the most economical or satisfactory manner.

PRELOAD WATER TANKS

BY J. J. CLOSNER*

[*Read January 16, 1958.*]

The history, development, use and acceptance of prestressed concrete tanks justify their consideration for any storage project.

1. The Preload Co. started designing and constructing prestressed concrete tanks in the mid 1930's. An early example of this work is the 50-ft diameter by 100 ft high, 1.5-mg standpipe constructed for the city of New Britain. Constructed in 1936, it has required no maintenance and is still in constant service. In 1943, Preload introduced its wire winding methods which have been in successful use throughout the world ever since. This mechanical method of prestressing tanks is the only United States method of prestressing, including linear methods, which has been exported for extensive use in foreign countries under license agreements. Operations have been or are under way in Algeria, Australia, Canada, Cuba, Colombia, France, Great Britain, Italy, New Zealand, Peru, Union of South Africa, Uruguay and others.

2. Through 1947 some 470 tanks had been constructed to Preload designs totaling 166 mil gal. This averages 350,000 gal per tank. Since 1947 and through 1957 over 660 tanks have been constructed to Preload designs; these total one billion gal and average 1.5 mil gal per tank. This sharp rise and increase in use in the past decade strongly indicate the widespread acceptance of this method of construction. These tanks have been built for ground and elevated water storage, water treatment, sewage digesters, petroleum storage and many other industrial applications.

In recent years the use of prestressed concrete for larger and larger tanks has become evident. Last year saw the completion of two 292-ft diameter, 13-mil gal tanks for the city of Reading, Pa. (see Fig. 1). Gilbert Associates, Inc., were Consulting Engineers. The year 1958 will see the city of Springfield, Mass., advertise for bids for two 15-mil gal tanks, 320 ft in

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FIG. 1.—TWO 13-MIL GAL PRESTRESSED CONCRETE RESERVOIRS AT READING, PA.—292 FT I.D. BY 27 FT 4 IN. SWD. (*Preload Co.*)

diameter, for addition to their Provin Mountain Reservoir. Bogert and Childs Associates are the over-all consultants. The East Bay Municipal Utility District of Oakland, Cal., is now constructing a 10-mg tank. This utility has nearly 40 prestressed concrete tanks in service.

In brief then, Preload tanks are not something new; prestressing is not a fad; it's a tool to be used by the resourceful designed to help his client solve a storage problem.

With that background perhaps we should define a prestressed concrete tank. What is it?

> A concrete tank is considered to be prestressed when it is designed and constructed so that when the tank is full, the ring forces created do not cause any circumferential tensile stress in the concrete. Since a prestressed concrete tank is designed as a cylindrical shell with edge restraint, vertical moments result when the tank is initially prestressed and moments of opposite sign but of less magnitude result when the tank is filled. These moments and the resulting tensile stresses, and how to reinforce for them are probably the most important aspect of prestressed concrete tank design. A tank wall may be reinforced vertically by prestressed or mild steel reinforcement or a combination of both, depending on the magnitude of the residual tensile stress. In any case of residual tension mild steel reinforcement must be provided.
>
> In a Preload-type prestressed concrete tank, the uniformly stressed circumferential prestressing is so designed and placed that no circumferential tensile stresses are created when the tank is full. The Preload tank also provides a well-balanced design for the vertical moments due to edge restraint, temperature differentials, backfill, etc., so that total bending tensile stresses are low.

In the above description of a prestressed concrete tank, you will note a strong emphasis on the matter of vertical bending stresses. We accept as axiomatic that no circumferential tension can occur in a wire-wound Preload tank; therefore, the major emphasis in design is found in the problem of vertical bending.

Our current practice in designing tanks, including full design criteria, is described in detail in our Bulletin T-19, "Design of Preload Tanks", which is available on request. These criteria are accepted by agencies of the Federal Government, the Portland Cement Association and many municipalities.

3. Since 1953, Preload has been using a rubber pad at the base of the wall and under the dome ring of dome-roofed tanks,

in order to reduce the edge restraint as much as possible (see Fig. 2). This feature has made possible very great improvement in Preload tanks. Dumbbell-type rubber water stops are used

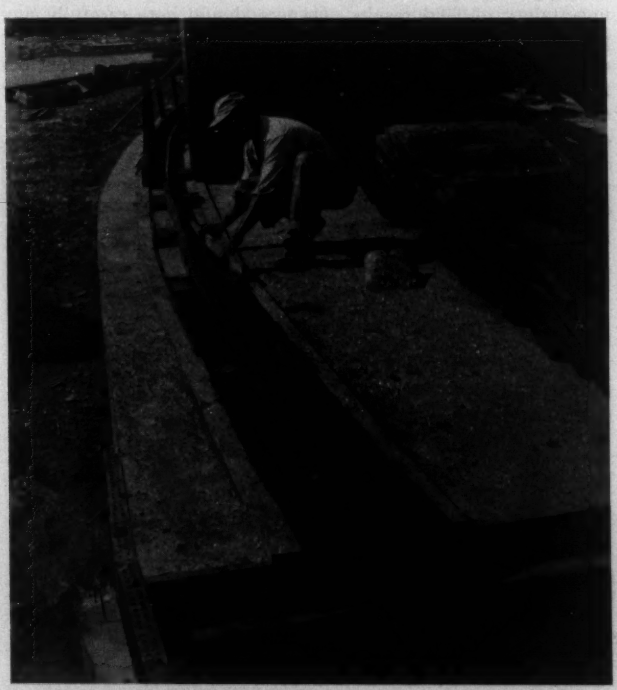

FIG. 2.—BASE-JOINT DETAIL OF PRESTRESSED CONCRETE RESERVOIR AT READING, PA. WALL WILL FLOAT ON 5-IN. BY 12-IN. BY 2-IN. RUBBER PADS. (*Preload Co.*)

between the footing and wall, and in all floor and wall construction joints, so that positive joint tightness is assured. With the rubber pad, on which the wall floats, the restraint is accurately determined from shear-resistance data of the rubber furnished

by the manufacturer. Vertical bending due to edge restraint is reduced to about 30% of that resulting from even the best of sliding-joint preparation, abandoned by Preload because of the uncertainty of field results. Owners should note carefully any proposed designs based on sliding-base details, as nearly 50% of the circumferential prestressing usually must be applied before static friction is overcome and sliding starts. Until sliding does start the base must be considered as hinged and the vertical stresses analyzed accordingly. The rubber-pad base joint contains patented features.

An example of the effect of edge restraint on the vertical stresses is shown in the following table taken from Preload Bulletin T-19.

	Rubber-pad base		Sliding base (coef. of friction — 0.5)	
	Outside face	Inside face	Outside face	Inside face
Tank Empty				
Dead Load	+ 61	+ 61	+ 61	+ 61
Base Restraint	+ 175	— 175	+ 445	— 445
Summation	+ 236	— 114	+ 506	— 384
Temperature	— 70	— 70	— 70	— 70
Summation	+ 166	— 184*	+ 436	— 454*
Tank Full				
Dead Load	+ 61	+ 61	+ 61	+ 61
Base Restraint	+ 29	— 29	— 335	+ 335
Summation	+ 90	+ 32	— 274	+ 396
Temperature	— 169	— 169	— 169	— 169
Summation	— 79	— 137	— 443	+ 227

*For the same stresses for both designs provide (454 — 184) = 270 psi with vertical prestressing: (32,500 lb per ft of wall).

4. The construction of the floor, core walls and roofs of Preload tanks follow sound standard construction practice, and may be of concrete or pneumatically applied mortar, depending on the size of the tank.

Floors for Preload tanks may be of either 4-in. poured concrete or 2-in. pneumatic mortar. In each case ½% of reinforce-

ment, each way, is provided. Pneumatic mortar floors normally do not have expansion joints. Poured concrete floors are usually subdivided for ease of pouring, but each construction-expansion joint is sealed with a rubber waterstop. For best results floors should be kept moist or flooded with a thin layer of water until the tank is placed in service.

The walls for Preload tanks may be built of either concrete

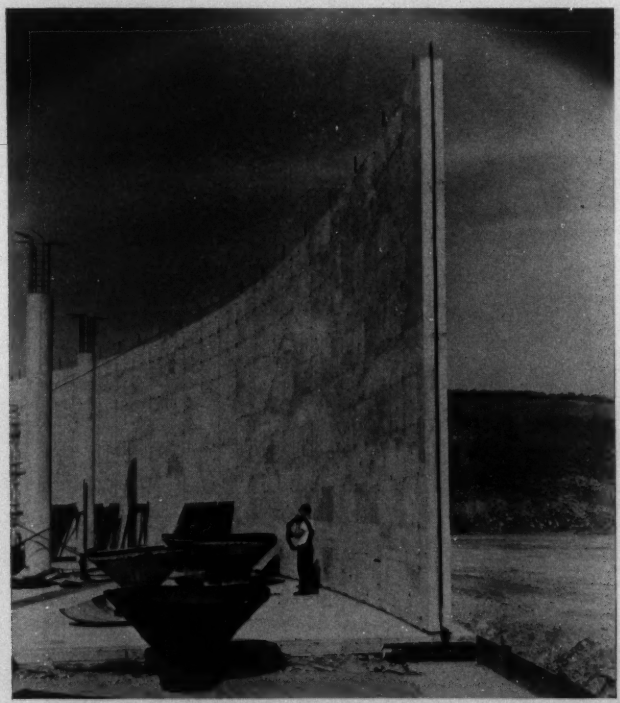

FIG. 3.—VIEW OF 13-IN. CORE WALL OF PRESTRESSED CONCRETE RESERVOIR AT READING, PA., SHOWING WATER STOPS. (*Preload Co.*)

FIG. 4.—ROOF OF 5-MIL GAL PRESTRESSED CONCRETE RESERVOIR AT GRAND PRAIRIE, TEX.—167 FT I.D. BY 30 FT 7 IN. HIGH. (*Preload Co.*)

FIG. 5.—ROOFS OF TWO 2-MIL GAL RESERVOIRS OF COMMONWEALTH WATER CO., SUMMIT, N.J.—93 FT I.D. BY 40 FT HIGH (*Preload Co.*)

or pneumatic mortar. It is usually economical to use pneumatic mortar when the walls are less than 6 in. thick; concrete when they are thicker. In each case, the forms are designed and erected in accordance with standard construction practice. Cast-in-place concrete walls are usually constructed in segments of full height (see Fig. 3). Rubber water stops are used in all vertical joints. After the walls have been shot or poured, they are allowed to cure and reach a strength of at least 1.8 times the initial circumferential compressive stress before the circumferential prestressing is applied. Vertical reinforcement as required by the design may be prestressed or standard mild steel bars, or a combination of both. The prestressed reinforcement usually is composed of high-strength bars or wire cables similar to those used for prestressing bridge girders.

Roof design for Preload concrete tanks may be dome, cast-in-place flat slab, precast flat slab, or cable-suspended, the choice being dependent upon the basic tank design or operating requirements (see Figures 4 and 5).

5. The recommendations of the Joint Committees on Standard Specifications, ACI-ASCE, for Concrete, Reinforced Concrete and Pneumatic Mortar form the basis of Preload construction specifications, practice and recommendations. Detailed Technical Specifications for the construction of Preload tanks are available on request.

A circular tank is prestressed by winding high-strength wire around the concrete core wall with a self-propelled machine, riding on and around the wall of the tank (see Fig. 6). The wire is stressed by drawing it through a die of smaller diameter than the normal wire. This operation is similar to the wire-drawing process used in the mills for making the wire. Accurate stress levels are obtained and the stress around the tank is uniform because there is no slippage of the wire on the tank wall after it is in place in its stressed condition. A stress-measuring instrument is available on each job, to check the wire stress on the tank.

After the circumferential reinforcement has been placed, a coating of pneumatic mortar is applied to the outside wall, to bond the wire to the wall and provide permanent protection against corrosion (see Fig. 7). For complete protection the ex-

terior coat of pneumatic mortar need be no more than 5/8 of an inch thick. When the design of the tank calls for multiple layers of wire, each under layer is given a 1/8-inch protective coating. The pneumatic mortar also lends a highly attractive appearance to the finished structure and requires no maintenance (see Fig. 8).

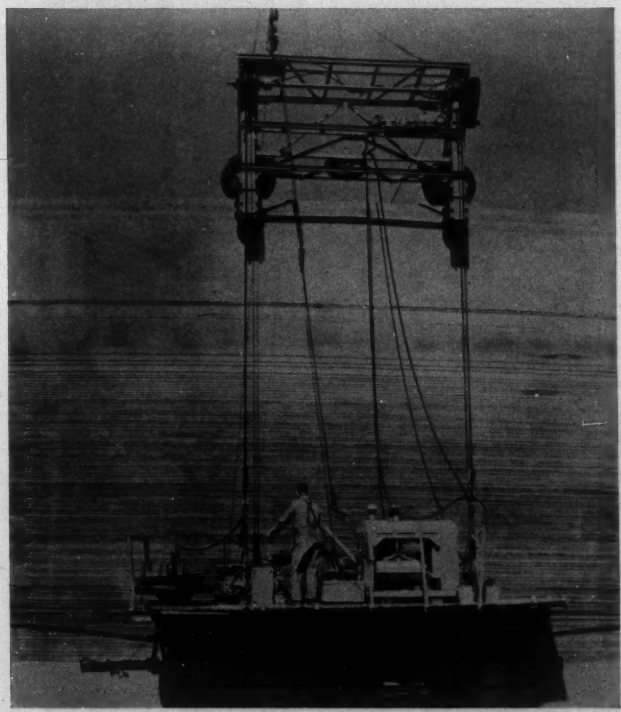

FIG. 6.—PRELOAD, HEAVY-DUTY, MERRY-GO-ROUND WIRE WINDER, STRESSING 0.192 WIRE TO 150,000 PSI INITIAL STRESS ON RESERVOIR AT READING, PA.

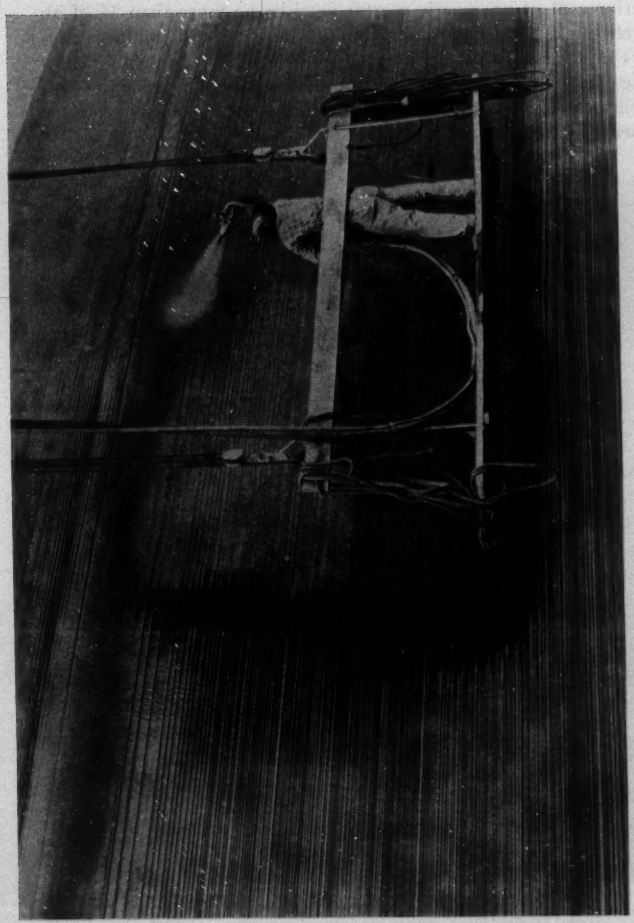

FIG. 7.—PNEUMATIC MORTAR COVER-COATING FOR WIRE PROTECTION ON PRESTRESSED CONCRETE RESERVOIR AT READING, PA. (*Preload Co.*)

Preload, its construction licensees, or competent local general contractors experienced in reinforced-concrete work can successfully and economically built Preload tanks. Where local general contractors are to perform the general concrete work, Preload or one of its licensees will serve as a sub-contractor for the specialized portions of the work. We have intentionally "de-

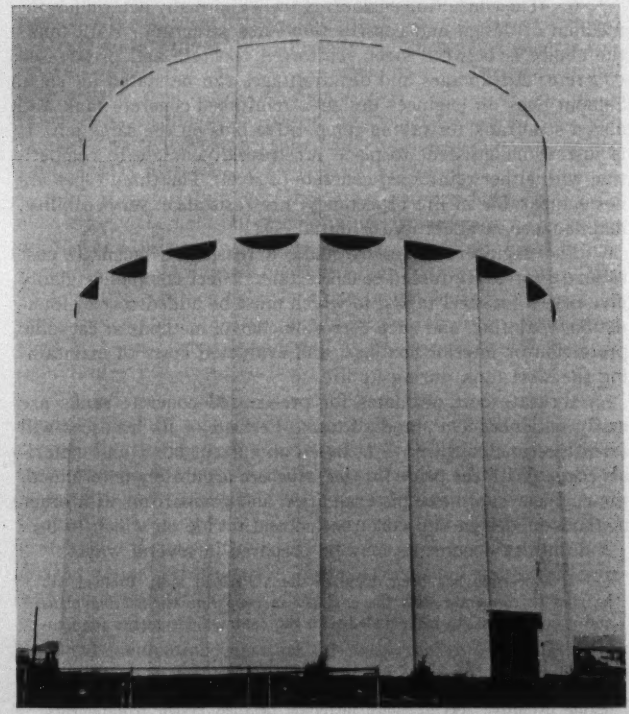

FIG. 8.—TWO-MIL GAL, PRESTRESSED CONCRETE, ELEVATED WATER TANK AT DALLAS, TEX.—98 FT 6 IN. DIAMETER BY 35 FT HIGH ON 83-FT TOWER. (*Preload Co.*)

signed out" troublesome construction details and simplified construction requirements. To assist the local consultant or inspection group of the owner, Preload has an "Inspection Check List" which provides helpful hints. It is also an inspection guide to assist the contractor, by proper inspection, in meeting the intent of the plans and specifications. Preload can furnish a field engineer for special inspection duties, if desired.

6. The consulting engineer or owner normally determines the medium of design and construction for a structure. With tanks the choice is between steel, reinforced concrete and prestressed concrete. Advantages and disadvantages can be stated for each. Seldom does an engineer design a reinforced-concrete tank and also a steel tank for taking competitive bids on the same job. It is just as inconsistent to place prestressed concrete in competition with either reinforced concrete or steel. The three types are not comparable in life expectancy, fire resistance, serviceability, maintenance, availability, or initial cost.

The engineer can easily make a reasonably accurate cost estimate for a reinforced-concrete tank. Steel companies gladly give prices for steel tanks, to which must be added cost of foundations, painting, and such corrosion-control methods as cathodic protection or interior coatings, and evaluated costs of maintaining the steel tank during its life.

Accurate cost estimates for prestressed concrete tanks are easily obtained. On standard tanks Preload or its licensees will furnish estimates within 5%, based on current labor and materials costs. With the price for the structure accurately determined, the engineer can make his evaluation and comparison with other methods of design and construction and decide on which to use.

Contract documents may be prepared in several ways:

(1) If a decision has been made to use a Preload tank, Preload will be glad to cooperate with the engineer in preparing engineering plans and specifications, to be included with the contract documents for issuance for bids.

(2) In lieu of (1) above, or if alternative methods of construction are decided on, then Preload will cooperate with the engineer in preparing definitive specifications, including detailed design requirements, to be incorporated with the contract documents. Bidding contractors should file copies of design calculations and drawings with their bids.

(3) In special cases of alternative bids, and after Preload has had an

opportunity to review the proposed alternative methods, it may be suggested to the engineer that engineering drawings for the prestressed concrete tank should be prepared and issued in the interest of the client. In such case Preload will assist in the prepartion of such plans, as in (1) above.

In some cases the owner has elected to negotiate with Preload for the furnishing of the prestressing work for the project for a lump-sum price that represents a small percentage of the cost of the complete tank. This price can be included in the contract documents with a stipulation to all bidding general contractors to include this sum as an allowance item in their bid. The general contractor will then engage Preload or one of its licensees as a sub-contractor for the specialized work. This procedure is particularly well suited to situations where only a Preload tank is desired.

Local material prices, labor rates and conditions will influence greatly the final bid price of a prestressed tank, just as they do for any other construction. Since a Preload tank is constructed with form-work, concrete and reinforcing steel, over 75% of the contract price is spent in the local community for labor and materials. This should be an important point when steel tanks are being considered, as the percentage of local expenditure is just about reversed.

Based on average United States conditions, the larger-capacity Preload tanks are generally more economical than conservatively designed reinforced-concrete tanks. Smaller tanks may show no economy in initial cost, but the advantages of prestressed design frequently justify the selection of a Preload tank. Preload tanks may cost slightly more in bare initial cost than ground-storage steel tanks. However, steel elevated or underground tanks generally are more costly than comparable designs in prestressed concrete.

Since alternative methods may be considered, a complete economic evaluation must include the cost of maintaining the facility during the bond period or service life. In comparison with steel tanks, the cost of adequate regular maintenance becomes a substantial item of cost. Depending on local conditions, proper inspection and maintenance of steel tanks will average 2.5¢ to 4¢ per square foot of maintained surface. This should

include floor, interior and exterior surfaces of walls, and roof. With column-supported roofs the structural system involves a considerable area and should not be disregarded. It must be realized that prices will increase as they have in the past; therefore, the present maintenance dollar will have to be nearly doubled to represent the average cost for a 25-year period.

In summary, the engineer and owner should look on prestressing as another medium with which to build his storage tank, whether it be underground, surface or elevated. This is not a new material or concept; it is a recognized and accepted solution.

PRESTRESSED WATER TANKS

BY FRANCIS X. CROWLEY*

[*Read January 16, 1958.*]

It is difficult, if not impossible, in the short period of 20 minutes to cover the essential elements of modern prestressed tank construction. Therefore, I shall confine my remarks to what seem to me to be the important features of prestressed tanks as they are built today.

The original prestressed tanks designed by William S. Hewett in the early 1920's were built of concrete, based on a compression stress of 500 psi, and of mild steel at a design stress of 18,000 psi tension.

The modern prestressed tank built by the National Gunite Corporation uses gunite at a design stress of 1,800 psi and high-tensile wire at a design stress of 140,000 psi. In addition we incorporate within our wall a continuous sealed diaphragm as an extra safety factor against penetration of water through the wall.

We believe that these three changes,

1. Gunite construction;
2. High design stresses in gunite and steel;
3. Steel diaphragm,

are the most significant improvements in prestressed tank construction in the last 30 years.

The change from concrete at low stress to gunite at high stress was the most obvious and for that reason the first important improvement in prestressed tank construction. Gunite, which is pneumatically applied mortar, is denser, stronger, more durable and more resistant to freezing and thawing than ordinary concrete. The fact that it can be placed in thinner sections makes possible the thin shell design for the dome and the flexible lining for the floor. Furthermore, to this day, gunite is the

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only practical material for covering and protecting the prestressing wire.

Another not so obvious advantage of gunite construction in prestressed walls is that it is by its very nature laminar. Consequently, it is well-nigh impossible for defects to be superimposed precisely on one another in successive layers through the wall.

The 2-in. gunite dome provides the standard cover for most prestressed tanks. It is durable, attractive and economical. Despite the misgivings of most laymen, who hesitate to walk on a 150-ft-diameter dome which is only 2 in. thick, it has astounding strength. The gunite dome has the further advantage of being "clear span", eliminating troublesome columns.

Gunite also found an especially suitable application in the 2-in. gunite floor for water tanks. Because of its trouble-free performance, principally due to its denseness and flexibility, the 2-in. gunite floor has come to be recognized as the best floor available. Another feature which makes this type of floor desirable is its ease of repair, should failure occur due to unexpected, major uneven settlement in the foundation.

The second and perhaps the most important single development in prestressed tank construction was the introduction of high stresses into the gunite and steel. Of course, by now, prestressed concrete and high stresses have become synonymous to engineers throughout the world.

Among the first to recognize the importance of high stresses in prestressed tanks was J. M. Crom, then of the National Gunite Corp. Disregarding advice from Hewett, Crom continually strove for higher and higher stresses, especially in the steel. His efforts ultimately culminated in the development of a wire-winding machine that laid the wire in place at a uniformly high stress and at an economically rapid rate.

The importance of this development to the prestressed-tank industry can scarcely be overemphasized. Wire winding is to the prestressed tank as the keystone is to the masonry arch, for only with high-tensile wire can we be assured that these tanks will remain prestressed and not degenerate into a conventional reinforced-gunite tank.

A few simple calculations will illustrate why it is economically impractical to achieve full and permanent prestress with

low steel stresses. Early efforts in the design and construction of prestressed tanks utilized rods and turnbuckles, to apply the prestress to high-carbon steel bars with an ultimate stress of about 60,000 psi. The maximum initial stress that can be used on this type of steel without excessive relaxation is 40,000 psi. Current thinking is that a permanently prestressed tank requires a reserve for cumulative losses from shrinkage, plastic flow and relaxation of at least 30,000 psi and perhaps 35,000 psi.*

Therefore, the allowable working stress in the steel is derived as follows:

Initial stress	40,000 psi
Less stress loss allowance	30,000 psi
Working stress	10,000 psi

Compare this to the modern tank using high-tensile wire:

Initial stress	140,000 psi
Less stress loss allowance	30,000 psi
Working stress	110,000 psi

This means that the rodded tank must use 110,000 psi ÷ 10,000 psi, or 11 times as much steel, in order to achieve the safe stress-loss reserve.

The rodded tank is similarly uneconomical in the use of gunite. The amount of gunite required in the wall is directly proportional to the initial prestressing force. In a rodded tank, the required initial prestressing force is 40,000 psi ÷ 10,000 psi, or 4.00 times the working force.

In a wire-wound tank, the initial prestressing force is 140,000 psi ÷ 110,000 psi, or 1.27 times the working force. Thus, the safe gunite requirement for a rodded tank is $\frac{4.00}{1.27}$, or 3.15 times that of a wire-wound tank.

Moreover, Crom's machine application provides uniform prestress in the steel, in contrast to the rodded tank with its overstress at the turnbuckle and understress at the middle of the

*This reserve is conservative for wire-wound tanks but is not conservative for rodded tanks, where additional reserve should be provided for friction losses due to the resistance of the rod to sliding on gunite.

rod. Thus it was that Crom's wire-winding machine changed the entire course of the prestressed-tank industry.

A development of similar import came along about 1950, again a result of the Crom genius. This was the use of a continuous steel diaphragm, embedded within the wall.

This diaphragm is economically feasible because it serves a threefold purpose. It acts

1. As a form against which we shoot gunite from both sides;
2. As vertical reinforcing steel for the wall;
3. As a seal against penetration of water through the wall.

The diaphragm is light gauge and is "Z"-shaped vertically, thus gripping the gunite mechanically from both sides. It comes in panels about 2 ft wide and 10 ft high. The panels are lapped horizontally and vertically, and the joints sealed with a waterproof plastic material. With the diaphragm the structure in effect is a steel tank, embedded within a prestressed gunite tank.

These three things—the gunite, the steel liner and the wire winding—are the basic ingredients of the most foolproof prestressed tanks ever built. When applied with the experienced hand of those with years in the business, and when tempered with sound engineering judgment and good construction practice, they will insure the owner of maintenance-free water storage for many generations and low-maintenance service for the centuries.

MANGANESE REMOVAL WITH CHLORINE AND CHLORINE DIOXIDE

BY A. E. GRIFFIN*

[*Read at Chemists' Session, Feb. 20, 1958.*]

Manganese is a common source of annoyance in a water supply. Unless special measures are taken, such as oxidation with potassium permanganate, chlorine or chlorine dioxide, or precipitation with lime at high pH values (pH 10.0-11.0), as in excess-lime softening, manganese will pass through the filters and slowly oxidize in the system, where it will deposit as black manganese dioxide and a small but unknown amount of other oxides of manganese. When this occurs the interior walls of clear wells and the interior of distribution systems will become coated with black manganese oxides, mixed in with bacterial slimes. Exceptional disturbances in the distribution system, such as flow reversals, sudden heavy flows, rapid changes in pH of the water or introduction of water from a new source, will loosen the deposits, causing what is known as "black water". This happened in Holland about the turn of the century to the extent that the event has gone down in history as the "black catastrophe". Nothing of this magnitude has been reported in the United States, but as long ago as 1940 in Sioux Falls, S. D., manganese-dioxide deposits were so great that the carrying capacity of the feeder pipes from the treatment plant to the city was seriously reduced. Currently, in El Paso, Tex., slime growths containing manganese slough off with drastic changes in water flow or with reversals of water flow. At Salt Lake City, Utah, the accumulation of manganese is so rapid in a 40-mile concrete conduit as to require mechanical cleaning on a yearly basis. If more than a year elapses between cleaning, black chunks of manganese-bearing slimes pass into the distribution system whenever the velocity of the water increases materially. Inasmuch as the conduit carries irrigation as well as potable water, these surges can occur at unanticipated intervals. Manganese has caused difficulties of

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one kind or the other in all parts of the country, including Washington, Louisiana, Georgia, New Jersey and New England. There seems to be a belt of manganese-bearing ground water reaching southward from North Dakota to Louisiana and eastern Texas.

Manganous manganese may be present in well waters and in impounded surface waters. In many instances iron is also present, but in a surprisingly large number of cases manganese is the main component. Newly impounded surface waters almost invariably develop manganese troubles within a year after impoundment, sometimes sooner, even though no traces of manganese have ever been detected in the contributory streams. This build-up of manganese content in impounded water is attributed to the leaching of manganese from the soil and organic matter on the reservoir bottom. The manganese content in such instances seldom exceeds 1.0 ppm, but it may go as high as 8.0 ppm. As much as 20 ppm and perhaps more has been reported to be present in the bottom of certain T.V.A. lakes. During turnover periods the manganese will become equally distributed throughout the depth of the reservoir.

Manganese is what might be termed a "foxy" element. In its reduced state it does not react with ortho-tolidine and defies easy detection. It does not oxidize readily at pH values below 7.0, and thus much of it may slip through the treatment process only to precipitate slowly in the distribution system. When post-lime is added for pH correction, its conversion rate to manganese dioxide is greatly accelerated. Ordinary coagulation with alum cannot be depended upon to remove manganese. It will be removed by excess-lime softening. Aeration, which is so effective in the oxidation of iron, may have little effect on manganese unless the pH of the water at the time of aeration is in the range of 10.0. Free available-chlorine residuals will oxidize manganese quite rapidly, but chloramine residuals have little, if any, effect on it (See Fig. 1). Chlorine dioxide oxidizes manganous manganese very rapidly at normal pH values found in water treatment and in the presence of ammonia.

Other methods of manganese removal include (1) base exchange, (2) aeration and contact with manganese-bearing ores, (3) use of the Zapffe Process,[1] (4) potassium permanganate

[1]Zapffe, Carl. U.S. Patent 1,990,214 (Feb. 5, 1935).

RELATION OF TYPE RESIDUAL
TO MANGANESE REMOVAL
SIOUX FALLS, S. D. NOV. 15 - DEC. 5, 1941

NOTE: ALL SAMPLES COLLECTED FROM FILTER EFFLUENT.
TREATMENT CONSISTS OF CHLORINATION - AERATION
CONTACT FILTER - SETTLING - SAND FILTRATION.

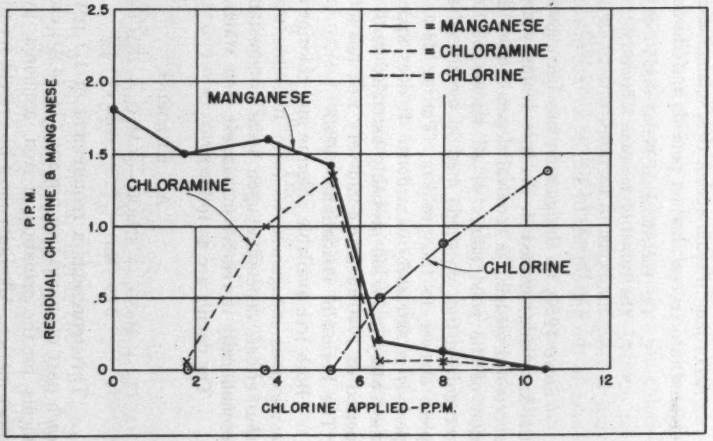

FIG. 1.

treatment, (5) copper catalysis or (6) ozone. Each of these methods has been used with varying success. However, the use of chlorine and chlorine dioxide is widely practiced with outstanding success.

According to some authorities,[2] manganese removal has been divided into several distinct periods as follows:

1. The Bacteriological Period (1836-1906)
2. The Period of Inorganic Chemistry (1906-1914)
3. The Period of Physico-Chemistry (1914-1922)
4. The Period of Catalysis (1922-1930)

Since 1930, no designation has been given, but in view of the knowledge gained in the intervening years, it appears that successful manganese removal depends upon the proper integration of the good points of all known methods with the full recognition that no single method mentioned above is the complete answer to the problem. Placing date lines on progress periods is extremely hazardous. It does appear, however, that the Catalytic Period probably extended until about 1940. The period of 1940 to date could very well fall into the category of "The Period of Oxidation" (1940-).

Both free available chlorine and chlorine dioxide react with manganous manganese to form insoluble manganese dioxide; thus either, depending upon local circumstances, can be used economically to remove manganese from water.

The details are as follows:

A. Chlorine

$$(1)\quad \underset{71}{Cl_2} + \underset{54.9\ (Mn)}{MnSO_4} + 4NaOH \longrightarrow \underset{\text{ratio of } 1.3:1}{MnO_2} + 2NaCl + Na_2SO_4 + 2H_2O$$

This represents a requirement of 1.3 parts of chlorine for each part of manganese present (71:54.9), exclusive of requirements for the oxidation of iron, ammonia, hydrogen sulfide or other matter. Alkalinity must be present for this reaction to take place, and the greater the alkalinity and the higher the pH, the greater the rapidity at which this reaction proceeds. The chlorine must be in the form of free available chlorine, otherwise the reaction will not take place. This means that Break-Point Chlorination must be used if ammonia is present.

[2]Zapffe, Carl. Jl. A.W.W.A., 25:5, 655 (May, 1933).

Chlorine oxidation of manganese is relatively slow and at pH values approximating 7.0 may require 2-3 hours or more. The rate of reaction increases as the pH and amount of free available chlorine increase.

Although oxidized manganese is insoluble in water, the particles are very small and at first have a tendency to pass through the filters. Within a very short time, however, after the chlorination process is started, the sand grains usually become jet black if manganese alone is present, and deep mahogany if iron is also present. This is said to be due to the plating-out of manganese dioxide and iron. When this occurs it is presumed a catalytic effect takes place, which deposits manganese on the filter media. This deposit should not be cleaned off, because this will allow the manganese to pass through the filters until a new coating of black manganese dioxide has a chance to re-grow. Some question has been raised as to the deleterious effect of increased sand size resulting from such practices. This question is at least partially answered by the experience at Lincoln, Nebraska, where the sand grains for some 20 years have been jet black and there has been no need to replace the sand in even one filter.

B. Chlorine Dioxide

In discussing chlorine dioxide for manganese oxidation, it is necessary to consider both the generation of chlorine dioxide and, in turn, its reaction with manganese.

Chlorine-dioxide generation

$$(1)\quad \underset{226}{2NaClO_2} + \underset{71}{Cl_2} \longrightarrow \underset{135}{2ClO_2} + 2NaCl$$
$$\qquad\quad 1.68 \qquad 0.52 \qquad 1.0$$

This shows that 1.68 parts of sodium chlorite (80%)—with reagent grade of 100% sodium chlorite, this figure would be 1.34—and 0.52 parts of chlorine are needed to produce 1.0 part of chlorine dioxide.

Chlorine dioxide is prepared by merging chlorine water from a chlorinator with a solution of sodium chlorite from a chemical solution feeder in a reacting tower filled with Raschig rings.

The pH of the mixture of chlorite and chlorine must be 3.0 or less; otherwise a satisfactory yield of chlorine dioxide will not

be realized. To ensure such a pH the concentration of the chlorine in the chlorinator injector hose must be 500 ppm or greater.

Reaction of chlorine dioxide and manganese

(2) $2ClO_2 + MnSO_4 + 4NaOH \longrightarrow MnO_2 + 2NaClO_2 + Na_2SO_4 + 2H_2O$

135 54.9 (Mn)

or

226 (as $NaClO_2$, 80% purity):54.9

∴

4.12 parts: 1.0 part

This means that 4.12 parts of sodium chlorite are required to oxidize 1.0 part of manganese. With the cost of sodium chlorite at $.80 per lb and chlorine at $.12 per lb, it thus costs $28.87 to remove each 1.0 ppm manganese from 1 mil gal of water, excluding the cost of oxidizing the iron, ammonia, hydrogen sulfide or other substances present. The presence of ammonia does not affect the oxidation of manganese. This eliminates the necessity of Break-pointing the water. Furthermore, the action of chlorine dioxide is much more rapid than the action of chlorine. Very frequently these attributes are the deciding factor when a choice of the two oxidizing agents is in balance. The same amount of alkalinity must be present as for chlorine. Increasing the pH or the use of an excess of chlorine dioxide does not appear to affect the rate of oxidation.

Chlorine dioxide is used alone or in combination with chlorine. It usually is more economical to precede chlorine dioxide with chlorine, because by so doing the ordinary chlorine demands will be satisfied with the cheaper chlorine, and the chlorine dioxide will be left to work on the manganese alone.

In summary, it is evident, according to the literature, that manganese is a common ingredient in domestic water sources throughout the United States. Unless it is removed it can be the cause of a variety of difficulties, ranging from stained laundry to clogged water mains. The preferred means of removal seem to revolve around chlorine and chlorine dioxide. When chlorine is used, a free available-chlorine residual must be present. Chlorine dioxide, on the other hand, oxidizes manganese quickly in the presence of ammonia. The major drawback to the use of chlorine dioxide is cost.

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THE MOST TROUBLESOME ALGAE IN NEW ENGLAND WATERS

BY E. A. SNOW, JR.*

[*Presented at Chemists' Session, Feb. 20, 1958.*]

The following table has been prepared as a summary of algae known to cause taste and odor troubles in New England. Many sources have been used, as well as the author's personal experience, covering the last 30 years (1928-58).

It was thought that this table might be of some use to water department superintendents as a guide both to the most likely trouble makers among the algae in this region and to treatment of reservoirs for the elimination of troublesome algae. More detailed information may be found in the references.

In our work we have found it expedient to use the highest dosage of copper sulfate when several odor-causing algae are present at the same time, since this eliminates all of the genera at one stroke.

We had intended to add a table of chlorine dosages but, since chlorine readily combines with the ammonia present in all natural surface waters and reduces the effectiveness of the dosage, it is considered better to leave the actual dosage up to the authorities, basing the effective dosage on one ppm of free available chlorine. This latter dosage will have a better killing power and also reduce the taste in most cases.

In connection with the copper-sulfate dosage listed, if one compares these with the dosages given in Hale's article, for example, one finds that I have given the maximum dosage in each case. The reason for this is that it is better to kill off the algae on the first dosage, rather than to have to go back and use a larger dose the next time. The best guide, however, is experience, and if one is dealing with a reservoir known to respond to lower doses, these should be used. Some algae have been found to be resistant to copper sulfate, notably *Anabaena*.

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N.B.—Any opinions expressed are those of the author only.

MOST TROUBLESOME ALGAE IN NEW ENGLAND WATERS

Phyla Genus	Meaning of genus name	Approximate size in S. U. or microns	Factor for size in areal standard methods	Dose $CuSO_4$ (ppm)	Odor and/or taste
Cyanophyta:					
Anabaena	"I rise or go up"	0.5 S.U.	#1 use area of clump	0.5	Grassy to nasturtium; when decayed = pigpen
Aphanizomenon	"invisible but alive"	0.2 S.U.	#1 use area of clump	0.5	Grassy to nasturtium; when decayed = pigpen
Clathrocystis	"a latticed pouch"	2 x 6 S.U.	#1 use area of clump	0.25	Grassy to nasturtium; when decayed = pigpen
Coelosphaerium	"a hollow ball"	3 S.U.	#1 use area of clump	0.33	Sweet, grassy
Chrysophyta:					
Asterionella	"little star"	0.2 x 2.8 S.U.	0.5	0.2	Geranium to fishy
Tabellaria	"little tablet"	0.7 x 0.9 S.U.	7/8	0.4	Geranium to fishy
Synedra	"knit together"	0.2 x 2.8 S.U.	3/7	0.5	Earthy**
Mallomonas	"a unit (cell) with a lock of wool"	8 x 25 μ	(#1)	0.5	Violet to fishy
Synura	———	100 x 400 μd.	(#1)	0.25	Cucumber to fishy*
Dinobryon	"powerful seaweed"	12 x 35 μ	0.5	0.18	Fishy rockweed
Uroglenopsis	"a wonder or curiosity with tails"	300 μd.	(#1)	0.2	Fishy oily (cod-liver oil taste)

N.B.—#1. As these algae vary greatly in size, the area they cover is estimated by squares.
* Chlorine changes and increases the taste.
** Also causes trouble by penetrating sand filters.

MOST TROUBLESOME ALGAE IN NEW ENGLAND WATERS (*continued*)

Phyla Genus	Meaning of genus name	Approximate size in S. U. or microns	Factor for size in areal standard methods	Dose $CuSO_4$ (ppm)	Odor and/or taste
Pyrrophyta:					
Cryptomonas	"hidden unit or cell"	20 x 30 μ	0.5	0.5	Candied violets
Glenodinium	"a wonder whirl"	30 x 40 μ	2	0.5	Fishy
Peridinium	"to whirl around"	40 x 48 μ	5	2.0	Fishy, like clam shells
Ceratium	"having horns"	95 to 700 μl.	15	0.33	Vile stench and rusty brown color
Chlorophyta:					
Chlamydomonas	"a unit with a cloak"	5 x 15 μ	0.25	1.0	

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Odor and Taste:

See above: Hale, Whipple and Swartz.

Other:

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PROCEEDINGS

April 1958 Meeting

Old Storrowton Tavern, West Springfield, Mass.

Thursday, April 17, 1958

The New England Water Works Association held its Southern New England meeting on April 17, 1958, in West Springfield, Mass. More than 243 members and their guests inspected the Bear Hole Treatment Plant and Pumping Station, including a 60-mg reservoir contained by an earthen dam, a 3-mgd slow sand-filter plant, and a 4-mgd vertical-turbine pumping station.

Luncheon was served at the Old Storrowton Tavern, Eastern States Exposition Grounds. President George G. Bogren introduced those at the head table. Ernest B. Jones, Chairman of the West Springfield Board of Water Commissioners, welcomed the group and was most gracious in his remarks.

A paper, entitled "Operating Experiences with the West Springfield Water System", was read by Carl M. Jacobson, Superintendent, West Springfield Water Department.

A paper on "Design and Construction of West Springfield Water-System Improvements" was read by Philip W. Sheridan, Engineer, Tighe & Bond, Consulting Engineers, Holyoke, Mass.

May 1958 Meeting

Hotel Brooks, Brattleboro, Vt.

Thursday, May 15, 1958

The Northern New England meeting of the New England Water Works Association was held in Brattleboro, Vt., on Thursday, May 15, 1958, with 140 members and guests present.

The group met at the Hotel Brooks and proceeded in an escorted motorcade to Pleasant Valley Reservoir, where the new improvements, which included a new spillway and a raised section of the dam, were viewed.

After a luncheon at the Hotel Brooks, President George G. Bogren introduced those at the head table. The Superintendent of Public Works, Justin A. Holden, was most cordial in his welcome of the group to Brattleboro.

A paper, entitled "Raising Pleasant Valley Reservoir Dam at Brattleboro, Vermont", was read by Joseph A. Kestner, Jr., Consulting Engineer, Troy, N. Y.

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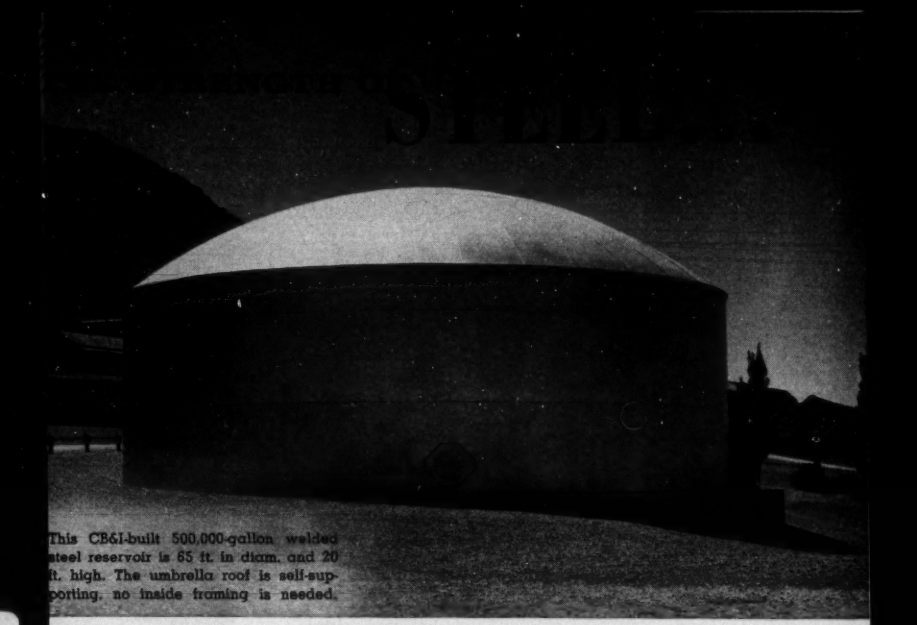

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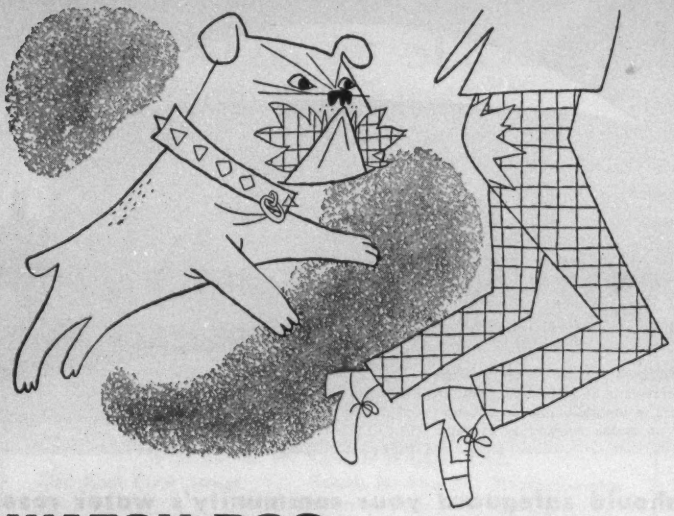

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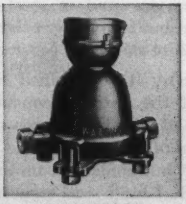

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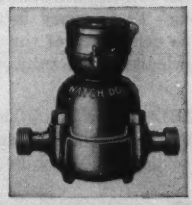

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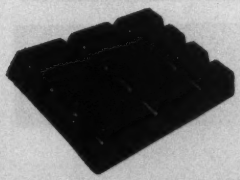

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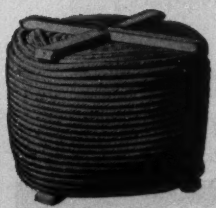

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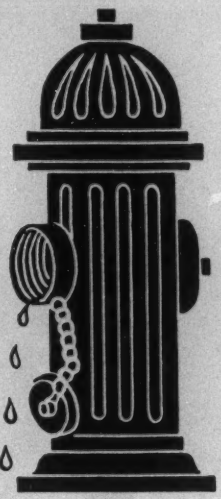

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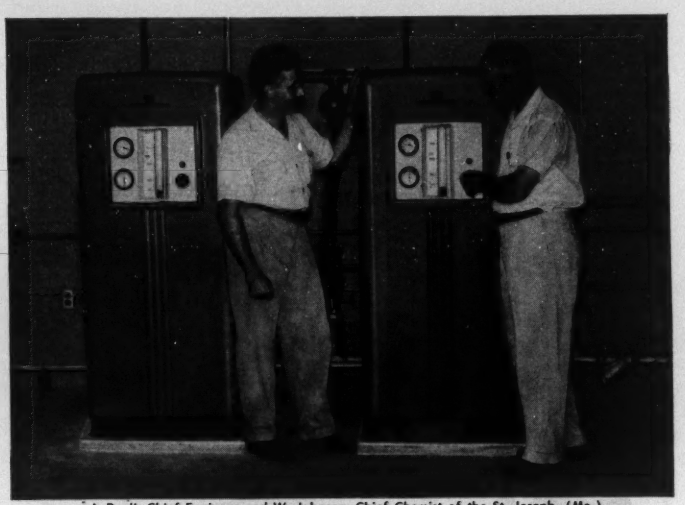

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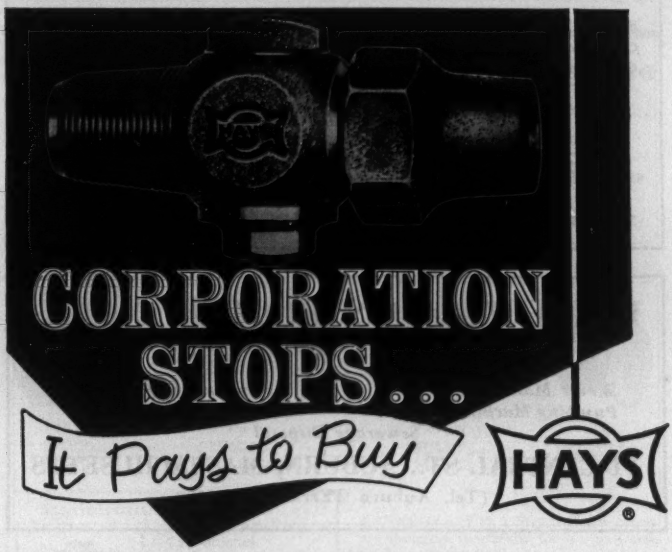

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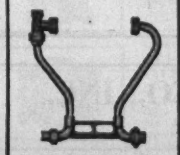
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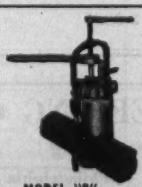
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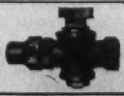
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. . . that conform to A.W.W.A. specifications in all respects

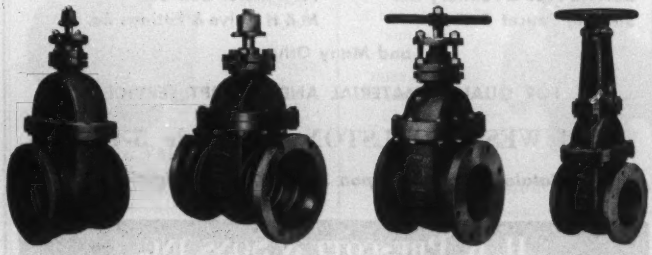


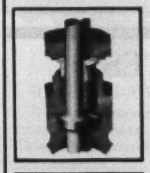
FIG. 50
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Bell Ends

FIG. 571X
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Mechanical Joint Ends

FIG. 561
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Flanged Ends

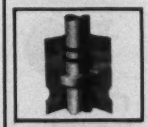
FIG. 555
- Outside-Screw-and-Yoke
- Rising Stem
- Parallel Seats
- Flanged Ends

Construction features . . .



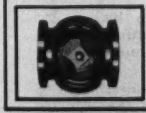
Conventional stuffing box

with adjustable gland has ample space for packing that conforms to Federal specification HH-P-106c. The bottom face of the stuffing box flange is faced smooth to form a bearing surface for stem thrust collar.



O-Ring seals

once installed no adjustment of any kind is required. The top O-Ring is the dirt seal and the bottom O-Ring is the pressure seal.



Operating nut

is Higher Strength Cast Iron. The base flange, with arrow indicating direction to open, is shaped to permit access from ground surface to adjust gland nuts with an extension socket wrench.

KENNEDY A.W.W.A. Standard gate valves are designed specifically for use in water works systems. Conforming to A.W.W.A. Specifications, in several particulars these valves exceed these standards of strength and refinements of design.

While A.W.W.A. Specifications cover only bell end and flanged end non-rising stem valves, the KENNEDY line also includes outside-screw-and-yoke valves and a wide variety of pipe connections including: Bell Ends, Flanged Ends, Mechanical Joint Ends, Universal Pipe Ends, Asbestos Cement Pipe Ends, Screwed Ends, Ring-Tite Pipe Ends and Spigot Ends.

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FIRE HYDRANTS

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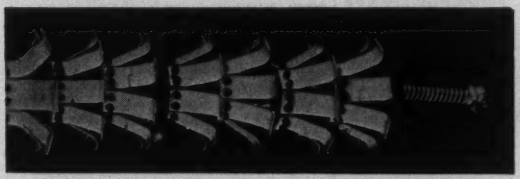

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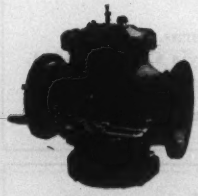
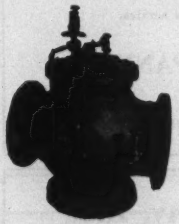


Controls elevation of water in tanks, basins and reservoirs

ALTITUDE VALVE

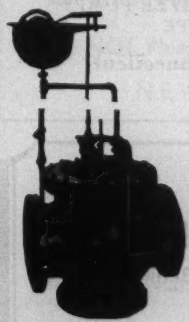
1. Single Acting
2. Double Acting



Maintains desired discharge regardless of change in rate of flow pressure

REDUCING VALVE

Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.



Maintains levels in tank, reservoir or basin

1. As direct acting.

2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

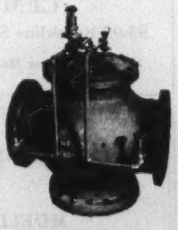
FLOAT VALVE

A self contained unit, with controls three or more automatic

COMBINATION VALVE

Combination automatic control both directions through the valve.

Maintains safe operating pressures for conduits, distribution and pump discharge



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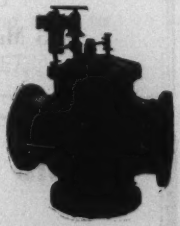

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No need for bell holes or caulking... no nuts or bolts to fasten. Simply fit a specially designed rubber gasket

U.S. CAST IRON PIPE FOR WATER, SEWERAGE AND

easy!

into the bell, and slide in the connecting pipe. The gasket insures a tight, permanent seal. And you can lay Tyton Joint pipe in wet trench or rain.

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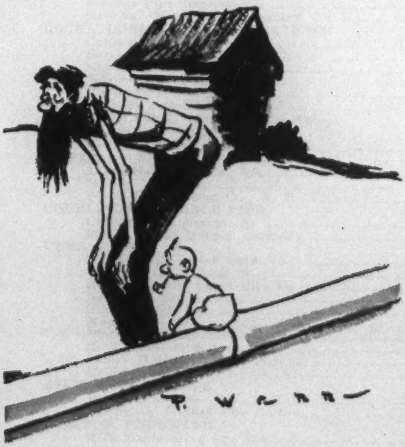

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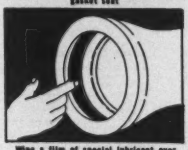
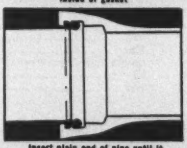
ONLY FOUR SIMPLE ACTIONS

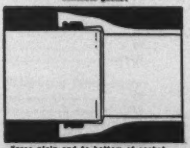
Insert gasket with groove over bead in gasket seat



Wipe a film of special lubricant over inside of gasket



Insert plain end of pipe until it contacts gasket



Force plain end to bottom of socket... the job's done!

Tyton Joint pipe for water main extension in Oklahoma.

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